EVOLUTION

CHAPTERS ON EVOLUTION

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'LEISURE-TIME STUDIES' 'LEAVES FROM A NATURALIST'S NOTE-BOOK'

ETC.

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TO

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VICE-CHANCELLOR OF THE UNIVERSITY OF LONDON,
PRESIDENT OF THE LINNÆAN SOCIETY,
ETC.

IN ADMIRATION OF HIS WORK AND LABOURS IN

THE CAUSE OF SCIENTIFIC EDUCATION,

THIS VOLUME IS

RESPECTFULLY DEDICATED.

PREFACE.

As the objects intended to be subserved by this work are explained in the introductory chapter, there is little need for a formal preface. It may, however, be well to state that the chief aim of the work is to present, in a popular and readily understood form, the chief evidences of the evolution of living beings. In this view, whilst I have been content to assume the reality of that process, I have also endeavoured to marshal the more prominent facts of zoology and botany, which serve to prove that evolution, broadly considered, is not merely a name for an unknown tendency in nature, but is an actual factor in the work of moulding the life with which the universe teems. A considerable experience as a biological teacher has long since convinced me that the hesitancy with which evolution is accepted, and the doubt with which even cultured persons are occasionally apt to view this conception of nature, arise chiefly from lack of knowledge concerning the overwhelming evidences of its existence which natural history presents. Doubtless a training in botany and zoology is required before the case for evolution can be fully mastered, but there need be no difficulty in the way of any intelligent person forming a just estimate of evolution upon even an elementary acquaintance with the facts of biology. I have accordingly sought to bring such facts prominently before the notice of my readers, and I would fain hope that even the complex topic of "development," itself a strong pillar of the theory of evolution, is susceptible of easy appreciation when the facts and inferences to be drawn therefrom are plainly stated. It would be invidious to mention any special sources to which I have been indebted for aid in the production of the present work: the field is so vast, that one must needs gather details from the stores of many workers: but I cannot refrain from expressing my indebtedness to the works of the late distinguished author of the theory of "Natural Selection," and to those of Professor Huxley and of Sir John Lubbock. My best thanks are due to the latter for his kind permission to use several illustrations from his interesting work on the relations between insects and flower-fertilisation. The illustrations as a whole will, I trust, be found to materially assist the comprehension of the most important points discussed in the various chapters.

A. W.

EDINBURGH: *October* 1882.

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CHAPTERS ON EVOLUTION.

I.

THE PROBLEM STATED.

THE year 1858 may be said to mark a distinct era in the science of biology, or that dealing with the structure, functions, development, and general history of animals and plants. On July 1, 1858, two papers were read before the Linnæan Society of London, which were destined to evoke and to direct an amount of criticism and research unparalleled in the annals of scientific history. It was then that Mr. Darwin and Mr. Alfred Russel Wallace laid before the scientific world the results of independent observations and reflections concerning the origin of the varied species of animals and plants which form the diverse population of the globe. Considering that the views expressed in the papers referred to had been formed and elaborated in entire independence of thought, and, indeed, in well-nigh opposite regions of the earth's surface, the harmonious nature of the conclusions arrived at by the authors was both interesting and surprising. Mr. Darwin's paper dealt with the Origin of Species; that of Mr. Wallace bore the title "On the Tendency of Varieties to depart indefinitely from the Original Type." The former, as naturalist on board H.M.S. "Beagle," had been "struck with certain facts in the distribution of the organic beings inhabiting South America, and in the geological relations of the present to the past inhabitants of that continent." Mr. Darwin further tells us that "these facts seemed to throw some light on the origin of species—that mystery of mysteries, as it has been called by one of our greatest philosophers." Mr. Wallace, on the other hand, exploring the Malay Archipelago, and interesting himself in the problems which the varied flora and fauna of the East suggested to the mind, formed opinions concerning the origin of species which, as we have seen, practically coincided with those of Darwin. In each case the inspiration, so to speak, came direct from nature, and from the unbiassed observation of the world of life itself—an origin this, as suggestive as it was appropriate for speculations including in their sweep and extent the entire organic universe.

The leading ideas of 1858 may be briefly and plainly stated. Mr. Wallace's conclusion may be summed up in his own expression, "that there is a tendency in nature to the continued progression of certain classes of *varieties* further and further from the original type—a progression to which there appears no reason to assign any definite limits—and that the same principle which produces this result in a state of nature will also explain why domestic varieties have a tendency, when they become wild, to revert to the original type. This progression," continues Mr. Wallace, "by minute steps in various directions, but always checked and balanced by the necessary conditions, subject to which alone existence can be preserved, may, it is believed, be followed out so as to agree with all the phenomena presented by organised beings, their extinction and succession in past ages, and all the extraordinary modifications of form, instinct, and habits which they exhibit." Mr. Darwin's views were no less lucidly expressed. He agreed essentially with Mr. Wallace in attributing the origin of new species to the modification of already existent animals and plants. The "Origin of Species" itself—a work first published in November 1859, and at present in its "thirteenth thousand"—represents the expansion and elaboration of Mr. Darwin's views of 1858, the publication of which raised at once a multitude of scientific critics, and invoked, it may be added, the rancour, bigotry, and often insensate, because ignorant, opposition of many persons outside the ranks of biological science.

To understand the meaning of the opposition which the views of Darwin and Wallace at first provoked, it is needful simply to take a brief retrospective view of the history of man's ideas regarding the origin of living nature, including, of course, the history of his own genesis. The opinions of 1858 were at first simply branded with the heterodox stamp, as preceding opinions had been similarly treated from the time of Lamarck in 1801, and, indeed, as every other statement which was not thoroughly "nail'd wi' Scriptur'," had been treated with the "apostolic blows and knocks" of those who seemed to claim a monopoly of all truth concerning the past, present, and future of the universe. The reason for the stormy reception of views concerning the species of animals and plants, promulgated as a matter of strict science, and formulated without any reference to other or more venerable opinions, can be readily enough understood, when it is added that the chief opposition to the "Origin of Species" came from the theological camp. Mr. Spencer remarks that "early ideas are not usually true ideas." He might have added with equal truth that early ideas, when woven into the texture of religious systems, are not given to lose their vitality with increasing age. At all events, the opposition to the views of Darwin, and to the evolution theory at large, were chiefly combated, not from any inherent error they were believed to contain, but simply because they ran in direct opposition to the older and more primitive conceptions of the origin of species which, formulated in creeds, and elaborated from pulpits, had come to be received as an article of unquestioning faith by cultured and uncultured alike. Two theories, and only two, concerning the origin of animals and plants, present themselves for examination and acceptation by the human intellect. Of these two theories, one dates from a pre-scientific period, when this earth was believed to be the centre of the universe, when this world was believed to possess a round and flattened surface, and when the sky was believed to be a solid roof environing the earth above, and constituting at the same time the floor of an upper and celestial sphere. Such rude ideas of cosmogony and astronomy were fully paralleled by as primitive a biological system. The various species of animals and plants were believed, according to the Mosaic cosmogony, to have originated each as a complete and "special creation." As man was conceived to have been formed of the dust of the earth, and as all the intricacies and complexities, structural, physical, and chemical, of the human organism were believed to have been set in action at once and perfectly, through the operation of a mysterious, supernatural fiat; so the varied species of animals and plants, from the monad to the elephant, from the plant-specks in the pool to the giant pine or lordly oak, were similarly held to have originated each as a "special creation." In this way a creative interference, capable of originating living beings *ex nihilo*, and therefore capable of literally creating matter—itself an inconceivable act—was credited on the first theory, as it may still be credited in creed and dogma, with the production of the entire universe of living things.

The genesis and development of such a theory has naturally been laid stress upon by most writers who have criticised, from an *a priori* point of view, the worthiness and acceptation of itself and its opponent hypothesis. The fact that the "special creation" theory was framed in an age when primitive ideas and mythologies, now completely consigned to the limbo reserved for exploded myths, constituted the philosophy of mankind, naturally militates against the truth and probability of the hypothesis in question. Being a primitive imagining, it would, according to Mr. Spencer's view, be most likely a wrong and untrue one. "If the interpretations of nature given by aboriginal men were erroneous in other directions," says that author, "they were most likely erroneous in this direction. It would be strange if, whilst these aboriginal men failed to reach the truth in so many cases where it is comparatively conspicuous, they yet reached the truth in a case where it is comparatively hidden." As we have to-day rejected the astronomy of the ancients, and as we no longer utilise their geology as serviceable or true, we can afford to dispense with their biological views, and we therefore turn hopefully to the second and scientific conception of the origin of living beings. This conception is the theory of "Derivation," "Descent," or "Evolution."

According to the evolutionist, the universe of life, instead of being composed of a series of fixed and unchangeable units—unvarying as when they were first "created" on the former theory of life's origin—is the theatre of incessant variation and change. Each "species" or "kind" of animals and plants, instead of existing as a stable unvarying group, as the older naturalists defined it, is seen to vary to a greater or less degree, according to internal and constitutional, or to external conditions, or under the influence of both combined. The progeny do not rigidly resemble the parents, but continually exhibit differences in colour, size, and other peculiarities. Thus "variations" in species are produced; and these variations may appear of singularly wide character when conditions favouring change have operated in their production. In this way the existing "species" are modified, and the new "varieties" thus produced, in time give origin to new species. These latter are, therefore, viewed as having been "evolved" by natural descent, that is by the ordinary laws of generation and reproduction, from the older species. The animal and plant worlds regarded in this light are liable to perpetual modification, and the experience of every-day life—seen familiarly in the culture of plants, and in the breeding of horses, cattle, sheep, dogs, and pigeons—amply testifies to the mobility and plasticity of the animal and plant constitutions. That is to say, man, in the process of breeding animals, and by selecting the parents of his domestic races, can "evolve" animals which, in time, differ from the original stock far more widely than ordinary and so-called "species" differ from one another.

But the plasticity of "species" is far from being the only prop and support of the theory of evolution. When the naturalist attempts to classify animals or plants, he discovers that instead of exhibiting each a specific and individualised structure, as might be presumed were the "special creation" theory true, the various groups of animals are linked together in such a fashion as to suggest the existence of some natural bond of relationship between them. With the plant world the case is analogous. The tribes of plants are harmoniously connected together in such a manner as to indicate a relationship which, as in the case of the animals, is only satisfactorily explained on the idea of connected descent. What explanation, for example, satisfying to the rational mind, can be given of such a striking feature as that illustrated in the literally marvellous correspondence which exists between the fore and hind limbs respectively of all vertebrate animals? How, on any other hypothesis save that of evolution, and of the common origin of the animals in question, can we explain why the arm of man, the wing of the bird, the horse's fore-limb, the dog's fore-leg, and the whale's paddle, are constructed on a common plan? Or, again, why should the bodies and appendages of lobsters, insects, spiders, and centipedes, be similarly identical in fundamental structure, unless on the theory of their common origin?

Again, from the region of Development, the evolutionist derives a whole host of cogent reasons for the faith he entertains in the soundness of his conclusions. All animals begin life under a similar guise—or, to come to actual details, as protoplasmic specks. In their earliest stages, the germs of a man and of an animalcule are indistinguishable. Furthermore, as human development proceeds along its lines, it assumes its own and special phases only after passing through stages which correspond more or less completely with permanent forms of lower animals. At first each quadruped is thus fish-like, and after successive developments leading it upwards through reptile and bird phases, it attains the quadruped type. But, even as a quadruped, the human organism itself declares its nobility of blood, only as a final feature in its early history. Of all other animals, the same recital holds good. Each animal comes to assume its own place as an adult through stages of development which repeat, as in a moving panorama, the phases of the lower life through which its ancestry has passed. The development of the *individual* animal is thus the brief and condensed recapitulation, often more or less obscured, of the development of the *race* or *species*. If facts like these be not admitted to prove the reality of evolution, then development as a whole must present itself as a series of the most meaningless paradoxes which it has been the fate of man to discover in the universe around.

Such are a few of the considerations—to be fully illustrated in succeeding chapters—which suggest that evolution is a great truth and a sober fact of living nature. Other topics of equal importance—such as the occurrence of rudimentary and useless organs in animals and plants, the existence of "links" between distinct groups, the results of degeneration, and other subjects—will also be found fully detailed in the following pages, which partake, indeed, of the character of a continuous series of proofs of the truth of the evolution theory. It requires, however, to be pointed out in the present instance, that whilst the general truth of evolution is now admitted by all competent biologists, there exists considerable diversity of opinion regarding the exact factors to which the processes of modification are due. Thus the title of Mr. Darwin's classic work is "The Origin of Species by Means of Natural Selection; or, the

Preservation of Favoured Races in the Struggle for Life;" and such a designation indicates with sufficient clearness that it was to "natural selection" that Mr. Darwin attributed the chief power in evolving new species through the modification of the old. Mr. Wallace accepts "natural selection" as a true factor, but he does not regard it as operating to the same extent in evolution as did Mr. Darwin. Other biologists, again, are inclined to adopt the idea that the evolution of living beings follows particular lines, along which the process is guided or directed partly by internal causes inherent in the constitution of the living being, and partly by external causes and by the surroundings of life. Concerning the relative importance of the various factors which biologists regard as of importance in determining the process of evolution, Huxley remarks that the exact place and power of "natural selection" "remains to be seen. Few can doubt that, if not the whole cause, it is a very important factor in that operation, and that it must play a great part in the sorting out of varieties into those which are transitory and those which are permanent. But," continues this high authority, "the causes and conditions of variation have yet to be thoroughly explored, and the importance of natural selection will not be impaired, even if further inquiries should prove that variability is definite, and is determined in certain directions rather than in others by conditions inherent in that which varies. It is quite conceivable that every species tends to produce varieties of a limited number and kind, and that one effect of natural selection is to favour the development of some of these, while it opposes the development of others along their predetermined lines of modification."

It forms no part of the purpose of this volume to discuss the merits of these varied views respecting the exact nature of the factors to which evolution owes its force and power. Perhaps any exhaustive account of this aspect of the subject is at present impossible with the materials at command. That which is infinitely more important in the first instance is the appreciation, firstly, of what evolution at large is and implies; and, secondly, of the proofs and arguments on which the existence and operation of this process may legitimately be based. A brief statement of the Darwinian theory of evolution may, however, be given, inasmuch as this aspect of the theory is that most frequently discussed and criticised both in scientific and in popular circles. It should be clearly borne in mind that the broad idea of evolution forms a foundation for every theory of the special fashion in which that process may be conceived to operate. "Darwinism" in this light is therefore to be regarded merely as one, but also as probably the strongest phase of those speculative endeavours to show the "how" of living nature, just as evolution itself has supplied the answer to most of the biological "whys."

The term "natural selection," applied by Mr. Darwin to his theory of evolution, is in itself a highly expressive designation. It indicates an analogy with that process of "selection" whereby man chooses the animals he intends to breed from. As by human agency, the special features of any given race may be brought to the front in the progeny, or as other characteristics may similarly be obliterated by gradual changes in the appearance, size, colour, and structure of the animal and plant units, so it is contended an analogous principle—that of "natural selection"—is traceable in the world around us. This process naturally tends to effect in nature the same or allied variations in species which man produces for a given end. In this view, natural selection is simply the natural result of a series of interactions between animal and plant life and its surroundings; and the gist of the process may be summed up in the statement that in the process of selection the weeded-out units die off, whilst the "selected" and stronger units, coming to the front, perpetuate their race, and thus tend, through their superiority and strength, to evolve new races and species.

It is an easy matter to summarise, in a series of propositions, the chief data upon which Mr. Darwin's theory rests. These propositions are as follows:—

Firstly. Every species of animals and plants tends to vary to a greater or less degree from the specific type. No two individuals are alike in every respect; each inherits from its parents a general likeness or resemblance to the species, whilst it tends at the same time to diverge from the parental form.

Secondly. These variations are capable of being transmitted to offspring; in other words, by natural laws of inheritance, the variations of the parents appear in the progeny along with the natural characters of the species. This much is proved in the "artificial selection" by man, for breeding, of those animals whose characters it is desired should be transmitted to offspring.

Thirdly. More animals and plants are produced than can possibly survive. Each species tends to increase in geometrical progression, and all the individuals produced could not find food, or even surface-area whereon to dwell.

Fourthly. The world itself (*i.e.* the surroundings of animals and plants) is continually undergoing alteration and change, represented by climatal variation, the rising and sinking of land, &c.

Fifthly. There ensues a "struggle for existence" on the part of living beings. Over-population means a struggle for food and for other conditions of life, such a consideration being really the doctrines of "Parson Malthus" applied to the animal and plant worlds at large. Hence it follows that as some forms will be better adapted (by variation) than others to their surroundings, the former will come to the front in the struggle. Nature, so to speak, will "select" those individuals which best adapt themselves to their surroundings, and will leave the rest to perish. This is the "survival of the fittest." The change of surroundings, already postulated, will further induce and perpetuate variations in those individuals which survive.

Sixthly. A premium is thus set by nature upon variation, inasmuch as the varying and surviving individuals will transmit their peculiarities to their offspring.

Seventhly. Thus "varieties" of a species are first produced; the "varieties" becoming permanent, form "races;" and the "races," in time, differ so markedly from the original species whence they were derived, as to constitute new "species."

Eighthly. Past time has been, to all intents and purposes, infinite. Hence it is probable that the existent species of animals and plants have been evolved (through "natural selection," acting through long periods of time) from a few primitive and simple forms of life, or possibly from one such form alone.

Such is a summarised statement of Mr. Darwin's views. His theory of "Sexual Selection" may be viewed as supplementary to that of natural selection, and as serving likewise to account for certain phenomena of which the former takes little heed. The process of sexual selection is that whereby the males of many species secure the females after contests. The result of these contests is that the stronger and victorious males will transmit to their offspring any peculiarities of form or constitution which they themselves possess, and in virtue of which they became victors over others. In this way variation is again seen to be favoured. Then, secondly, the "selection" of a mate is often determined, not by the males, but by the females. In such a case it is assumed that those males which exhibit (as seen typically amongst birds) special features in the way of colour, plumage, size, or ornamentation, will be preferred and chosen. Variations are thus once more produced; since the special characters of the male will be reproduced in the offspring, whilst the perpetuated accumulation of such characters will in due time modify the species and evolve new races therefrom. By aid of the theory of "sexual selection" Mr. Darwin accounts for many of the special features and possessions of animal races. Thus, the song of birds, the brilliant plumage and colours of many species, and the curious and peculiar ornamentation of many forms, altogether inexplicable on any ordinary theory of utility, are seen to be useful or necessary adjuncts, on the theory of "sexual selection," to the modification of species and to the evolution of new races.

The foregoing statement of the Darwinian theory will enable the reader to follow with greater advantage the arguments and illustrations adduced in the succeeding chapters in support of the evolution theory at large. It only remains in the present instance to indicate the order and succession in which the evidences of evolution are herein presented.

An account of the methods in which the study of modern biology or natural history is carried out, forms the subject of the second chapter. Such an account will serve to place the reader in possession of the chief data, from a knowledge of which the naturalist is enabled to construct a reasonable and harmonious series of details respecting the living denizens of the globe. The special inquiries of the biologist are duly noted, and the divisions of biology which supply answers to the pertinent queries of the scientific investigator are also detailed. Incidentally, the bearings of ordinary biological details on evolution are also discussed, and a suitable introduction is thus afforded for succeeding studies.

In the next and third chapter, the reader is made acquainted with the constitution of the animal and plant worlds. The knowledge of the general relationship of animals and of plants to each other, viewed in groups and as individuals, forms a necessary foundation for all biological studies, whether viewed in reference to the theory of evolution, or merely as a part of ordinary information respecting the universe of life as a whole. In this chapter, the bearings of the constitution of the animal and plant kingdoms on the theory of descent are duly detailed; and a sketch of the primary classifications of animals and plants is also included in the general history of the worlds of life.

The fourth chapter introduces the subject of "protoplasm." On the due appreciation of the relations of this substance as the "physical basis of life" to the constitution of the living body, rests the clear understanding of many fundamental points in connection with animal development. Similarly, the inferences which the evolutionist is led to draw from the universality of protoplasm as the common material of living beings, are only appreciable when the nature of this curious and all-pervading substance is set forth in detail. No step is possible in biological advance until the facts relating to protoplasm and its relations to life are mastered; and in the discussion of such a topic certain fundamental truths and propositions of biology therefore fall to be discussed.

Thus fortified and prepared by these introductory details, the evidences of evolution as the great process which summarises in itself the forces and tendencies of living beings fall to be noted. The first of these evidences is constituted by "rudimentary organs," and the tale they tell of animal and plant modification. Here the curious nature of these apparently useless parts is seen to be fully borne out by the idea that they refer "to a former state of things," and that they represent the natural, but deteriorated and vanishing remains of structures once useful in the ancestors of the animals that now possess them.

The sixth chapter strikes a somewhat related key-note to that touched in the preceding section. The evidence deducible from the modifications which animal structures have undergone is largely in favour of evolution. The structures specially selected for treatment in this chapter are the tails, limbs, and lungs. It is attempted to be shown that these organs illustrate in the clearest manner how adaptation to new ways of life is induced by alterations in the habits and surroundings of animal forms. Incidentally, information is likewise afforded respecting certain interesting aspects of the structure of higher animals.

The science of likenesses (or homology) forms the special topic of the succeeding section. Herein the general deductions of "homology" are discussed and illustrated from both animal and vegetable worlds. The broad likenesses between animals which were discussed in the third chapter, are here specialised, and the natural correspondence existing between parts and organs, often of the most diverse appearance, is duly dwelt upon. In its general tenor, this chapter will be found to follow out the line of argument specially selected in chapter sixth.

The subject of "missing links" is treated in the eighth chapter. No topic in all the wide range of evolution demands more detailed treatment than that of the "links" between apparently distinct groups of animals the existence of which the theory itself postulates, and the necessity for which is a matter of popular notoriety. The higher animals have been specially selected for treatment in this chapter, not merely because the case for evolution is more likely to be duly appreciated when these forms are selected for discussion, but because the evidence is overwhelmingly clear in favour of evolution when the higher groups are examined, and also because links in lower life are duly treated in succeeding chapters under the head of "Development."

The succeeding three chapters deal with the evidence afforded by development in favour of evolution. All evolutionists may be said to regard the deductions of embryology amongst the chief supports of their hypothesis. Hence, as the subject is not merely important in itself, but also somewhat technical in details, it has been judged advisable to discuss the problems of development at some length. In chapter ninth, the earlier stages in the development of animals at large form the chief topics treated. In the tenth section, two special groups—the *Echinoderms* or star-fishes, &c., and the *Crustaceans* (or crabs, lobsters, and their allies)—are selected for discussion; whilst in the succeeding section attention is directed to the special features observable in the development of the *Molluscs*, and of higher animals still.

The twelfth chapter, devoted to the "metamorphosis" of insects, is intended specially to show how the development of these animals presents us with a series of highly interesting illustrations of certain modifications affecting the young of animals as well as the adults. The origin of the wings of insects, and other details incidental to the structure and physiology of these animals, are also discussed in this chapter.

The thirteenth chapter revises, somewhat at length, certain problems in the constitution of animals which appear worthy of study; whilst incidentally the nature of the plant-constitution is also treated. Both topics are related to evolution in a broad sense; since the factors which determine the intimate constitution of the animal or plant must also perforce possess a large share of influence in modifying the worlds of life at large.

The fourteenth chapter, dealing with the "fertilisation of flowers," is intended to illustrate certain of the methods whereby, in the physiology and life of plants, the evolution of new races is favoured and assisted. No more typical examples of ways and means adapted to aid and inaugurate the primary conditions on which evolution depends and to ensure variation, could well be cited than this department of botanical science. The deductions from flower-fertilisation tend very powerfully, moreover, to support the doctrine of descent in other phases than those which are connected merely with plant-reproduction at large.

The fifteenth chapter, devoted to the subject of "degeneration," exemplifies the axiom that the ways of evolution include backsliding and retrogression as well as advance. Many animals and plants have developed all their characteristic features through their adoption of, and adaptation to, a lower way of life than that pursued by their ancestors; whilst whole groups of animals present features to the naturalist which could not be accounted for by any ordinary phase of evolution, but which the idea of degeneration, as a factor in working out the ways of life, has fully explained.

The concluding chapter deals with the relations of geological science to evolution, and sums up certain geological matters and aspects of evolution which have been cursorily alluded to in the preceding sections. The general development of life on the earth, as well as the more special phases with which the geologist has to deal, are shown to support evolution fully and completely. The history of life in the past correlates itself so completely and fully with that of life as it exists to-day, that the geological side of the argument in favour of evolution has come prominently to the front in every system which has had for its aim the exposition of the theory of descent.

It should, lastly, be borne in mind that the evidence for or against the theory of evolution must be judged chiefly by biological standards, and from the biological standpoint, if an accurate estimate of its probabilities, excellencies, and powers to explain satisfactorily the phenomena of life and structure is to be formed. The theory of descent has been frequently criticised, with scant success, however, from other points of view than the biological. But as a theory which, above all else, purports to present us with a rational account of the origin and modifications of living beings, it is evident that its weakness and its strength alike must be sought for within the domain which the naturalist claims as his own. Hence the succeeding pages may be viewed as an attempt to summarise in a popular form the chief details of the evidence, on the fair and rational interpretation of which the evolutionist is well content to rest the claims of his doctrine for intellectual assent and acceptance. In such a study, moreover, may be most readily found the materials for a comprehension of those aspects of the subject which lie somewhat apart from the main pathways of biological study.

The interest of the whole topic need hardly be alluded to in closing these introductory remarks. No subject which can engage the attention of the thinker in these latter days presents so many and varied avenues, leading to allied fields of inquiry, as the doctrine of descent. As applied to man alone, the evolution theory teems with interest, and suggests endless problems for the consideration of the metaphysician, the ethical philosopher, and the sociologist, not to speak of the multifarious features of anatomy, physiology, and geology, which the purely human phase of the theory presents to view. The concluding words of Mr. Darwin in the "Origin of Species" eloquently describe the varied interests which the subject evokes, and also summarise his own conclusions concerning the agencies which have wrought out the existing order of living nature. "It is interesting," says Mr. Darwin, "to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with Reproduction; Inheritance, which is almost implied by reproduction; Variability from the indirect and direct action of the conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and, as a consequence, to Natural Selection, entailing Divergence of Character, and the Extinction of less improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur," concludes Mr. Darwin, "in this view of life, with its several powers having been originally breathed by the Creator into a few forms or into one; and that whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms, most beautiful and most wonderful, have been, and are being evolved."

II.

THE STUDY OF BIOLOGY.

It may reasonably be supposed that every intelligent person is perfectly conversant with the term "Natural History," and with the common meaning usually attached thereto. As employed in ordinary life, or even in scientific circles, where exactness of language is a necessity for the clear expression of thought, the term has come to signify the study of the animal world. Hence, popularly, a "natural historian" is believed to be a person who is much at home in zoological gardens, in aquaria, and in all places where animal life is presented to view, for purposes of study, serious or otherwise. To correct popular and long-standing ideas, is a task for which no sensible person can have any great liking. Albeit that the task is often necessary, and in matters more serious than the nomenclature of science has to be undertaken as a matter of conscience, the work of reforming old-established notions of things is frequently the labour, not of one lifetime, but of many generations. Still, effort is, and must be, cumulative in its effects; and if in the present instance I can succeed in showing the rational use of the name "Natural History," I may perchance not merely preface this chapter by a necessary and appropriate explanation, but likewise aid in diffusing better, because truer, ideas of the aim and scope of natural science.

The term "Natural History" finds different meanings according to the latitude in which it is used, and according to the prevailing ideas which the name has been accustomed to convey to the minds of those using the name. In the north, for instance, in academic circles, the name is used to signify "zoology," or the study of animals alone. A student who, in a northern university, attends a class of "Natural History," is understood to concern himself solely with the animal population of the globe. Elsewhere the name has been used to indicate the study of plants and animals together; the student of "Natural History" in this latter sense, extending his researches into the field of "Botany," in addition to that of "Zoology." But a third meaning of the name comes to hand in which it is used, in strict accordance with its etymological significance, to signify, not the study of any one or two departments of nature, but to denote the whole range of natural science studies. Employed in this latter sense, the name "Natural History" is found to include not merely the knowledge of animals and plants, but the study of minerals and of the inorganic or non-living world at large; whilst it may also be shown to include the study of the planets, because, as a history of nature, it is bound to take account of everything whereof nature consists. To be a "Natural Historian" in this latter sense would imply a man's knowledge of the whole universe. But as human life, in one view at least, is conveniently short, and as wisdom and knowledge are apt to linger long, the most ardent devotees of science may reasonably shrink from laying claim to a full or even moderate knowledge of "Natural History" as thus defined. The "Admirable Crichton" in these days is an unknown creature; and although now and then a master-mind sweeps across the horizon of knowledge—although an occasional century may see a Darwin or a Helmholtz with a profound knowledge of nature-science in well-nigh all its branches—still, the bounds of this wide science of "Natural History," as we have defined it, threaten to prove beyond the powers and grasp of any one mind amongst us.

It will thus be seen that the correct use of the name "Natural History" is that in which it is employed to mean a knowledge of universal nature. This being so, what are the branches which this great science may be said to include? I have already indicated that geology and mineralogy, in addition to astronomy and natural philosophy (or physics), find a natural place within its limits. Chemistry is as truly a branch of natural history as geology, and when we have placed these sciences in the category of the "Natural Historian," there yet remains an important branch which in one sense may be said to unite the others, and which concerns itself with the living things of this world.

The child in his elementary lessons is accustomed to speak of the three kingdoms of nature. This division into animals, plants, and minerals is a perfectly correct method of parcelling out nature's belongings. Although possessing obvious relations with the animals and plants, the sciences of chemistry, geology, and mineralogy deal chiefly with the mineral, or lifeless, section of nature, as does natural philosophy, and its offspring astronomy. It becomes clear, then, that the interests of living things require to be considered under a special department of natural science. In former days, as we have seen, the "Natural Historian" was the scientific guardian of the animal and plant interests. Abolishing this phrase, what term, it may be inquired, do we now employ to indicate the study of living beings? The answer to this question may fitly conclude these introductory remarks. As Huxley has shown in his lecture "On the Study of Biology," whilst the name "Natural History" was used in the broad sense to include all departments of natural knowledge up to the middle of the seventeenth century, the growing specialisation of scientific studies tended thereafter to separate the sciences into the sciences of mathematics and experiment (such as chemistry, astronomy, and physics), whilst the sciences of observation (geology, mineralogy, zoology, and botany) remained to represent the wider "Natural History" of olden days. Buffon and Linnæus wrote their "Natural Histories" under this latter idea, namely, that they professed the study of rocks, fossils, plants, and animals. Further limitation of scientific aims and names was, however, soon necessitated by the increase of knowledge. It was clearly perceived that, as living things, the animals and plants remained more closely connected than did the geological and other branches of natural history. Hence, in due course, a new name crept into use to indicate the sciences which specially select life and living beings as subjects of study. In 1801 Lamarck, the French naturalist, first used the name "Biologie" to indicate the collection of sciences dealing with the manifold relations of animals and plants. There seems to be a faculty in the human mind for acquiring a liking for a name or method which exhibits a special appropriateness in its description of the objects it is destined to describe. And we find that, despite the firm hold which the name "Natural History" had obtained as descriptive of the study of life, it is being gradually superseded by the name "Biology"—in every sense a most appropriate term. Although chiefly in the northern parts of these islands we still cling with a striking proclivity, favoured by a reverence for antiquity, to the name "Natural History," the term "Biology" has already gained a secure hold as a scientific expression. To-day, when we study "Natural History," we should be understood to take the widest possible view of natural things; and we may include in our studies subjects as diverse as the origin of chalk-flints, the anatomy of the brain, the liquefaction of gases, and the fertilisation of flowers. But when we assert that we study "Biology," we thus limit, with some degree of exactness, the objects of research. Then, we take for granted that our studies limit us to the fields of life—to the history of animals and plants—a history which, be it remarked, however, stretches its interests far afield, and relates itself in many and diverse ways to other and even widely separated branches of knowledge.

Thus much may be said by way of introduction to the nature of biological study. In the field before us lie the manifold concerns of the world of life; and it is straining no analogy to assert, with Mr. Herbert Spencer, that "preparation in biology" may after all be the best preliminary for the successful study of the human race, and for the understanding and regulation of its interests, whether regarded as pertaining to the individual, the family, the race, or the nation at large. It is no startling thought that the laws of human life and society can be demonstrated to be founded upon wider laws which prevail in animal life at large, and that the analogies and resemblances betwixt the ways of humanity and the acts of lower life are too close to admit a doubt of their intimate relationship. Spencer is stating no mythical idea but a solid fact, when he remarks that "the Science of Life yields to the Science of Society certain great generalisations, without which there can be no Science of Society at all." Nor is the statement to be viewed as aught else than reasonable, that "all social actions being determined by the actions of individuals, and all actions of individuals being vital actions that conform to the laws of life at large, a rational interpretation of social actions implies knowledge of the laws of life."

Such a subject, however—the connexus between biology and human interests—would require a volume to itself; and at present I merely mention the fact of such relationship to impress the idea that the future of biology will undoubtedly include in its scope much of human affairs that now appears wholly at a distance from the interests of animals and plants at large. Nor have I the intention, at present, of discussing the relations of biology to religion, or of trenching even cursorily upon those modifications in religious opinion and in theological reasoning which, of all the sciences, biology has been most plainly instrumental in inaugurating and fostering. At present, therefore, we may simply endeavour to discover how biology is to be studied, to what that study leads, and the nature and direction of the paths wherein the modern biologist pursues his research. If, according to Spencer, "preparation in biology" is the great necessity for a true knowledge of the laws which govern human society, so, for us, preparation in the methods of the science of life is a needful preliminary for an understanding of the influence which modern biology has exerted upon men's ideas concerning the order and origin of living nature.

The study of the standpoints of biology may be fitly commenced by a reference to the manner in which the investigations of the biologist into the history of animals and plants are carried on. It is the province of science to be exact; it is the first and highest duty of its professors to secure correctness in their methods of discovering facts. In science we are not at liberty to begin anywhere, as, in truth, our researches, if pursued completely, will terminate in a definite fashion. Organised method is, in short, the great essential for scientific success in the pursuit and discovery of truth; and it is in his adoption of such methods that the scientific investigator differs most notably from the student in many other departments of thought. We may note in passing that another and equally important characteristic of scientific investigation exists in the fact that, having no prejudices to defend or prepossessions to consult, the man of science stands in no dread of the results to which he may be led, and is placed at no disadvantage when he replaces beliefs, however time-honoured they may be, by the newer phases of thought to which his studies have led.

Four very definite questions may be said to contain in their replies, the materials for constructing the full history of any living being. The queries to which I allude are such as the child might well ask respecting any object presented for the first time to his view; and it is worthy of note that the methods of inquiry through which the cumulative experience of ordinary life is gained find in the questionings of science a striking parallel. First, and most naturally, we inquire concerning the living being, "What is it?" Next in order comes the question, "How does it live?" Thirdly, the query, "Where is it found?" appears as a most natural inquiry; and the question, "How has it come to be what it is?" may fitly close the list of scientific interrogations. It may be said that, could we perfectly and fully answer these four queries as applied to any living thing, the history of such a form might be regarded as being in every sense complete. Its present history, its past existence, its way of life, its bodily mechanism, its evolution and descent—these, and other points in which the life and being of an animal or plant is summed up, are included in the replies to our four queries. Answer these questions fully, I repeat, respecting an animal or plant, and you leave no item in its history unexplained. When they shall have been fully answered respecting the known organic world, then will dawn a millennium in biological and other sciences, of which, however, not the remotest shadow of a dream has yet crossed the scientific expectation. Full as our knowledge is on many points of structure and life history, biologists too frankly recognise the gaps in their information to hope for or expect the completion of their science even in the most distant years that from the present horizon we care to scan. Still, the labour of investigation proceeds apace—slowly, it may be, yet hopefully; and every scientific advance which the present sees or the future may know, may assuredly be regarded as filling up, wholly or in part, one or more of the replies to the four questions wherein, as we have seen, the gist of biology is comprised.

The principle of the division of labour which has wrought such wonderful changes and improvements in human affairs, political, social, and commercial, has extended its advantages to the domain of life-science, in that each query possesses its allotted branch as the agent for supplying its answer. Part of the excellence of biological reasoning, and of scientific method at large, consists in the fact that the labour of investigation is divided amongst three well-marked branches of inquiry; whilst the answers to the fourth and last question on our list are in reality supplied by the concentrated knowledge of the three preceding replies. Thus, to the question "What is it?"

the science we name "Morphology" gives us an answer. This department of biology concerns itself with *structure* alone. Under this head we gain a complete knowledge of the mechanism of the living being. A watchmaker, taking a watch or clock to pieces to ascertain the structure of the timepiece, investigates its "morphology." An engineer, describing to a bystander the principles of the mechanism he has constructed, is similarly detailing its morphological composition. The structure and build of the living body—animal or plant, high or low organism, be it remembered—is investigated under this first head of inquiry. It is morphology which places before us the few facts of structure perceptible in the animalcule; and it is this science, in its highest development, which investigates the complexities of the human organisation itself.

But "morphology" can readily be shown to possess a subdivision into three important branches, each dealing with a special phase of living structure. There exists, firstly, the subdivision *Anatomy*, which deals with the structure of the fully developed (or adult) animal or plant. Next in order comes *Development*—a study all-important, as we shall hereafter see, in the eyes of modern biologists. Through development we obtain a knowledge of the manner in which the adult body, which "anatomy" investigates, came to assume its perfect and completed form. Development, in short, initiates us into Nature's manufactories, and shows us her methods of evolving living organisms. Just as even a rapid run through a watch-manufactory, and a glance at this table and that, or a look at the various stages in the progress of the watch towards perfection, would afford an idea of the fashioning and forming of the watch, so development gives us an insight into the process and method employed and followed in the formation of the animal or plant. The pin or pen we think so little of, came to be what it is through a highly complex process of manufacture. To thoroughly know what the pin or the pen *is*, we should naturally require a knowledge of how it *was made*. Just so in nature; development teaches us how the animal and the plant is made—nay, more, it tells us also, by the way, a wondrous tale respecting the causes of the manufacture, and the circumstances which have led Nature to frame her living possessions according to one fashion or another, and to relate, it may be, apparently diverse articles of her handiwork in the closest bond of intimacy and union. Last of all, a third department of morphology, or the science of structure, exists in the shape of *Taxonomy* or *Classification*. It is the plainest of truisms, that we can only classify and arrange any set of objects truly and satisfactorily when we really know the objects, and when we possess a perfect acquaintance with their structure. Hence "classification" falls into a most natural place when, after the acquirement of knowledge concerning the structure and nature of living beings, we are able as a consequence to place together those which are truly alike, and to separate those which are unlike.

By way of illustrating the application of morphology, and on the principle that example is better than precept, let us select as an example of scientific inquiry the history of a fish. Under the head of morphology, the biologist is bound to take account of every detail of structure which that animal exhibits. Through the aid of "anatomy" he will make its acquaintance as a fully formed being; he will ascertain the full details of its structure; note the form, number, position, and relation of its organs; and in general obtain a thorough knowledge of its composition and bodily mechanism. But anatomy does not inform him of the prior history of the fish; hence he turns to development as a means of showing him the manner in which the fish-body grew and was fashioned. Beginning as a small speck of protoplasm, indistinguishable from the matter which forms the whole body of the lower animalcule, he would trace for us the evolution of the complex body from materials of extreme simplicity. Hour by hour, and day by day, he would chronicle the changes in the division of the egg, the first appearance of the embryo, the beginnings of the heart-pulse, the formation of brain and nerve, and the outlining of body at large. And, finally, he would show how the completed being, evolved by strange artifice from literal nothingness, grows to its adult form and takes its place amongst the finished products of nature. Such are the details of development.

Finally; asking himself concerning the place and rank of the fish in the scale of creation, the biologist would turn to "classification" to aid him in his search. Ascertaining the structure and development of other fishes, he would know accurately enough the proper sphere to which science calls, and in which science places, the form before him. He would find cause to utterly reject classifications and systems of arrangement not founded upon a true knowledge of structure. The whale, for instance, is classified as a fish by primitive man—and, I may add, also by persons amongst ourselves, whose culture professes to be by no means of a low grade. It is fish-like in form and appearance; it inhabits the sea; its conditions of life are evidently those of the fish. Why, then, asks popular opinion, is the whale not a fish, seeing that in any case the latter is "very like a whale"? To this question the biologist can but reply, that if nature has modelled whale and fish on the same lines, he can have no quarrel with nature on that account. His, however, is the duty to assure himself that the fish and whale are really alike. Through anatomy he learns that, outwardly alike as the two animals are, things in this instance are really not what they seem. The fish, his study of morphology informs him, has cold blood, and a heart consisting of but two cavities or chambers: the whale, he finds, has warm blood, and a heart constructed on the same type as that of the biologist himself, and consisting of four chambers. The fish is covered with scales: the whale's body-covering consists typically of hairs; and whilst the fish out of water dies, as a rule, because its gills are then removed from the medium from which they derive the oxygen for breathing, the whale breathes by lungs, and, as every one knows, requires to ascend periodically to the surface of the water to inhale the air directly from the atmosphere, like ourselves. The whole internal economy of the fish, albeit that it exhibits the same general type as that of the whale, is of much less complex kind. And, not to penetrate more deeply into the distinctions which separate the whale race from the fish tribe, we may lay stress on one last fact of primary importance in distinguishing the two animals—namely, that whilst the fish was developed from an egg which was hatched externally to the parent body, the whale was born alive and was nourished in its early life by the milk-secretion of its parent. Now, all of these characteristics infallibly demonstrate to the merest tyro in zoology that, so far from a whale being in any sense a fish, it is a true "quadruped" or mammal like ourselves. It finds refuge in the same class which includes the kangaroos and their neighbours as its lowest members or democracy, and apes and man as its aristocrats. The whale, in short, is a mammal with but two well-developed limbs, and occasionally rudiments of two other members; the two front and developed limbs being converted into swimming-paddles or "flippers." It is a quadruped modified for an aquatic life, and resembles the fish only in the fact that its body is built up on one and the same general type, and in its outward modification as a tenant of the "vasty deep." Thus clearly do we observe that the true position of an animal or plant in the living series can only be determined by a reference to the facts of structure. Classification, in other words, is the natural termination to the work begun by the anatomist and the student of development.

Turning to the second question asked by biological science regarding every living being—"How does it live?"—we find the science of *Physiology* credited with furnishing the reply to this latter query. Physiology is the "science of functions," a term translatable into meaning that branch of inquiry which shows us how the living mechanism works, and how life is supported in virtue of defined actions which it is the duty of that mechanism to perform. The watchmaker or other artificer who, setting the mechanism he has constructed in motion, professed to instruct us in the manner of its working, would be showing us the "physiology" of the machine—just as previously, when describing its structure, he taught us its "morphology." We may go further still, and add, that, without a preliminary knowledge of structure, the intelligent appreciation of function, or working, is impossible of attainment. The exact manner in which a watch performs its duties can only be comprehended after an examination of its anatomy or the disposition of its parts. Hence, in living beings, "how life is carried on" is a question only to be answered from the knowledge and by the aid of the considerations which the examination of their structure affords and supplies.

Summing up the history of the living being in action which physiology writes for us, we may say that three great functions are performed by every animal and by every plant. The living being has first to nourish itself; to provide for the continual wear and tear to which, in the mere act of living and being, its frame is subjected. The first function of *Nutrition* thus provides for the support of the individual animal or plant. But death is continually thinning the ranks of animal and plant species. As local death, or the decay of the particles of the individual body, is a constant concomitant of individual life, no less true is it that general death is an invariable accompaniment of the life of the race or species. As nutrition—the act of taking and assimilating food—repairs individual loss, so the function of *Reproduction* repairs the loss and fills the gaps which death has made in the ranks of the race. New beings, through the exercise of this latter function, are brought into the world to take the place on the stage of life of the actors whose parts in the biological drama have already been played out.

Lastly, in the exercise of its living powers, the animal or plant is found to possess certain means for acquiring relations of more or less definite kind with its surroundings. An amœba—in its way a mere speck of protoplasm—is seen under the microscope to contract its jelly-like body when a food-particle touches its substance; and, as the result of the contact, the protoplasmic speck engulfs the atom in question and duly assimilates it. But for this property of sensitiveness, the life of the animalcule would be equivalent to the existence of the mineral; its power of nourishing its frame and of receiving food really depends on its sensitiveness to the outward impressions produced by the chance contact with its body of the external particles on which it feeds. Withdraw from the protoplasm this sensitiveness, and your animalcule would starve. Sensation and a power of acting, like human units of official nature, upon "information received" through sensation, is a universal attribute of life. Even the fixed plant may, as in the Venus's fly-trap (*Dionæa*), develop a more sensitive and elaborate apparatus for the capture of prey than many animals of tolerably high grade; and in all plants there exists living protoplasm which, as its first characteristic, exhibits sensitiveness and a power of contraction. A snail, irritated by touching the tip of its tentacles, withdraws into the obscurity of private life for a while, and indicates that it possesses not merely a nervous apparatus analogous to our own, but that such apparatus is used in an exactly similar fashion. A broad likeness exists between a snail's retirement into its shell when touched, and the human act of withdrawing the head from a threatened blow. And so we find that from the animalcule to man, from the lowest plant to the highest member of the vegetable kingdom, there exist means whereby the living being, through the property of sensitiveness or "irritability" (as we may term the general function of nervous tissue or its representative), is brought into relation with its surroundings. This act of relating itself to the outer world in which it lives, constitutes the third function of life wherever found. The nerve-acts whereby man is enabled to think, feel, and move; the actions whereby a daisy closes its florets when the chill of evening falls upon the world; the act of a Venus's fly-trap or a sundew in capturing the insects on which, like vegetable spiders, these plants feed; and the humbler manifestations of sensation seen in the sluggish movement of an animalcule or in the cells of a seaweed—are bound together in one harmonious function, which we name that of *Relation*, *Innervation*, or *Irritability*. To nourish itself, to reproduce its kind, and to maintain relations with the world in which it lives—such is the whole physiological duty of man and animalcule alike; and in the survey of these three functions is comprehended the answer to our second question, "How does the animal or plant live?"

The third inquiry of the biologist, as we have seen, relates to the place and position of the living being on the surface of the world—whether it be found on the earth itself or in the waters under the earth, whence by deep-sea research the knowledge of its habitat has been drawn. Every animal and every plant, besides a name and designation, possesses a "local habitation" on the earth's surface. The study of structure and the knowledge afforded by physiology take no account of the dwelling-places of animals and plants. "Where is it found?" is thus a question which must also be asked of the biologist; and for the answer we depend upon a third branch of biology, to which the name of *Distribution* has been given.

The purport of the inquiry, "Where is it found?" requires no explanation. The most natural of queries concerning a living being is that which the child might ask concerning the native habitation of an animal or plant. Outward nature appeals too forcibly to us to render the question, "Where does it come from?" an unnatural one when applied to the animal or plant; the difference between our own land and habitation and those of other men being included in some such interrogation as that involved in the questions which the science of Distribution professes to answer. No more interesting queries can well be imagined within the whole range of natural-history study than those included within the sphere of this third division of biology. Why, for instance, are kangaroos and animals of like grade only found in Australia and adjacent islands? Why are the opossums—near relations of the kangaroos—absent from the Australian home of their nearest kith and kin? and why do they occur in America, when natural expectation would have placed them in Australia? Why are antelopes well-nigh confined to Africa, which has no true deer, whilst the deers are otherwise world-wide in their distribution? Why are humming-birds only found in the New World, over the length and breadth of which they are widely distributed? Why are the monkeys of America absolutely different from those of the Old World? and why are those found in Madagascar, in turn, so varied from their neighbours of Asia and Africa? Why are sloths and armadillos only found in South America? Such are a very few of the queries which Distribution asks, and to which this science endeavours to supply an answer.

We thus perceive, clearly enough, that the situation and position of an animal or plant on the surface of the earth is no mere matter of chance, but is as much the result of law, and has been as clearly brought about by the circumstances which regulate existence as a whole, as its structure is the result of laws of development acting in definite fashion and ordered sequence. Distribution, it is true, is a biological science as yet in its infancy. It presents us, we may note, with two aspects, under one of which we settle the place and position of an animal in space, that is, in the world as it now exists—such is *Geographical Distribution*. Through the other aspect of this science, we determine, by the aid of the history of fossils, whether it had an existence in the past history of our earth, and if so, under what conditions it lived. This latter phase of the subject is named *Geological Distribution*, or distribution in time. The importance of distribution as a branch of biology grows and increases daily, as we perceive that the answers to many puzzles and problems of life are bound up in the replies we are able to furnish to the question, "Where is the animal (or plant) found?"

At this stage of biological investigation many naturalists might be tempted to call a halt. Having ascertained, as fully as may be, the structure, physiology, and distribution of an animal or plant, the investigation of the living form might be regarded as complete. Contrariwise, however, the tendency of the biology of past years has been to lay increasing stress on a fourth inquiry concerning every living thing—namely, "How has it come to be what it is?" Such a question is tantamount to the inquiry, "How and why was the living being created so?"—an interrogation which, even a few years back, would have sounded as an attempt to probe the mystery of divine intent, and which, as such, would have been relegated to the domain of the unscientific, if not to that of the impious as well. But considerations of theoretical impiety have no effect in face of the need for knowledge. If the speculation how any planet was framed, and if the formation of a nebular hypothesis, or the promulgation of a theory of elliptical orbits, was a warrantable procedure—nay, even a necessity—of astronomical knowledge, one may well be excused for failing to discover the unwarrantableness of speculation concerning the origin of animals and plants. Especially, too, if the way of creation, as biological science believes, has not been through successive acts of supernatural interference with the matter of life and the manner of living, but through the modification—slow, gradual, natural, and prolonged—of pre-existing species, the justification for the query, "How has this animal or that plant assumed its form and place in the world?" lies on the face of nature itself. If, as is apparent to all biologists at least, the way of creation is traceable in the forms and developments of living beings, we are bound to investigate that history, as a part of the duty laid upon scientific truth-seeking and upon biological investigation.

The impiety so much talked of in past years, but of which one happily hears but little now, if it exists at all, is illustrated solely in the absolute scepticism of those who refuse to admit and believe in the right of man to read and construe, as reason dictates, the records written in the fair face of creation itself. Persons who deem it impious in the scientist to assert that he can trace the evolution of this animal or that plant, present the best possible frame of mind for the development of the very scepticism the existence of which they are the first to deplore. The wilful folding of the hands in deprecation of scientific investigation, and the shutting of the eyes in a so-called "orthodox" and slumbering ignorance of the facts of nature, is the procedure of all others best calculated to sap the foundations of religion itself. It is such ideas which Dr. Martineau, with his accustomed ability, has ably denounced when he says, "What, indeed, have we found by moving out along all radii into the Infinite?—that the whole is woven together in one sublime tissue of intellectual relations, geometric and physical—the realised original, of which all our science is but the partial copy. That science is the crowning product and supreme expression of human reason. . . Unless, therefore, it takes more mental faculty to construe a universe than to cause it, to read the Book of Nature than to write it, we must more than ever look upon its sublime face as the living appeal of thought to thought." These are words worth reflecting upon; and they certainly admit from the side of liberal theology the full, free, and unrestrained right of science to investigate fully and hopefully whatever facts or aspects of Nature lie to her hand. They present, if need exists for such apology, the fullest justification of the scientific investigator's work, when he endeavours to trace through the mazes and byways of evolution the manner in which the living world and all that is therein comprised has been formed, moulded, and perfected as we now find it. If, therefore, as we shall hereafter see, there are means and ways, clues and traces, to be found in nature for the study of the method through which living beings have come to assume their existing order, it were but folly to deny our right to utilise such means to the full, and to extend that knowledge, the increase of which Bacon wisely declared tended to the relief of man's estate.

"*Ætiology*," or the "science of causes," thus supplies us with the reply to the last of the four queries which concern the nature of animals and plants. In itself, this branch of inquiry connects the other three departments. It utilises the knowledge which structure, physiology, and distribution collect and systematise. It supplies the natural termination to all inquiries respecting the history of living beings. Since we believe that the causes which have wrought out the existing order of nature have left traces of their operation in the living universe; which traces, like the silver thread running through the many-coloured pattern, serve to link together the interests and to show the harmonies which underlie the varied warp and woof of life.

To fix these methods of biological study the more firmly upon our minds, we may select, as the subject of a brief exposition, the natural history of a kangaroo—an animal form sufficiently distinct and specialised to render the details of its biological study a matter of easy comprehension. No animal form is more familiar as a being foreign to our own country than the kangaroo; and its history, like that of every other living being, familiar or otherwise, must be investigated along the lines we have just laid down. The question "What is it?" is answered by morphology; and a large number of very interesting replies would be found amongst the answers to the questions of the science of structure. We should thus be informed, as a primary fact of kangaroo history, that it is a *Vertebrate*, or "backboned" animal; that it agrees in the general type of its body with all fishes, reptiles, birds, and quadrupeds; and we should, moreover, speedily discover by even a cursory anatomical examination that it belongs to the quadruped class, and presents essentially the same general characteristics which all mammals or quadrupeds, from the whale upwards to the lion, dog, rat, sheep, ape, and man, agree in possessing. But the more personal history of our kangaroo would show wide differences in structure from the organisation of ordinary quadrupeds. We should be struck by the low type of its brain, as compared with the brain of ordinary quadrupeds. We should note two curious bones unknown in common animals, and which arise from the front of the kangaroo's haunch-bones. These are the so-called "marsupial bones," on which the "pouch" these animals possess is supported. In connection with this fact of kangaroo-structure, we should also discover that the young kangaroo is born in an immature condition, that it is thereafter transferred to the pouch of its mother, and that it exists therein for many days after birth, being duly nourished by the secretion of the milk-glands which open into the pouch. We might also note that the kangaroos, as every visitor to the Zoological Gardens knows, possess hind limbs which are developed out of all proportion to the fore-legs. In its resting posture, it sits upon a kind of tripod, or three-legged stool, formed by the tail and two hind limbs; and when the skeleton of the hind limb is examined, we find, further, that the great apparent length of the foot is in reality due to the elongation of the animal's instep bones. The foot, we may lastly note, possesses four toes, whereof one (the fourth toe) is very large and conspicuous. The fifth toe is smaller than the fourth; and the remaining two (placed to the inner side of the other toes) are very small, and united together by a fold of skin. There is no first or great toe in the kangaroo; and the two large toes forming the bulk of the animal's foot are the fourth and fifth toes: the two small and rudimentary toes corresponding to the second and third toes in ourselves.

Thus much a brief study of "anatomy" would teach us about the kangaroo. Of its development, nothing need be said beyond noting the fact that it is formed and fashioned after the manner, firstly, of all Vertebrates in general, and, secondly, of all other quadrupeds in particular. Kangaroo-development stops short, so to speak, at a lower level than the development of such an animal as a dog, and at a considerably lower level than that of an ape or a man. But, if any proof of the exact nature of the kangaroo were wanting, such facts as those elucidated by its development would at once and indisputably settle its relationship to ourselves, as a low member of our own great class.

Next as to its "classification." What, it may be asked, is the kangaroo's place in nature? As the claims of structure settled the place and position of whale and fish in the animal series, so the morphology of the kangaroo allocates to it a situation in the quadruped class. The structure of many other animals is found to present a striking likeness to that of the kangaroo. The opossums, the wombats, the native "bears" and "hyænas" of Australian colonists, the kangaroo rats, the phalangers, the bandicoots, and allied forms—all, with the exception of the opossums, confined to the Australian province—exhibit evident affinities to kangaroo structure. Relying upon structure—and development would be found to strengthen the evidence of morphology—we should place these animals along with the kangaroo in a special order of quadrupeds to which we give the name of *Marsupials*, or "pouched" animals. These animals would agree with the kangaroo not merely in lowness of brain structure, in the possession of the curious "marsupial bones," in the general arrangement and even special form of internal organs, and in the peculiar shape of the lower jaw, but also in the matter of the foot structure. Very striking is it to observe the prevalence of the one type in the feet of this varied assortment of quadrupeds. "How curious it is," says Mr. Darwin, "that the hind feet of the kangaroo, which are so well fitted for bounding over the open plains—those of the climbing, leaf-eating koala, equally well fitted for grasping the branches of trees—those of the ground-dwelling, insect- or root-eating bandicoots—and those of some other Australian marsupials—should all be constructed on the same extraordinary type, namely, with the bones of the second and third digits extremely slender and enveloped within the same skin, so that they appear like a single toe furnished with two claws! Notwithstanding this similarity of pattern, it is obvious that the hind feet of these several animals are used for as widely different purposes as it is possible to conceive. The case is rendered all the more striking by the American opossums, which follow nearly the same habits of life, having feet constructed on the ordinary plan."

The science of structure thus settles the questions which naturally arise respecting the relationships of the kangaroo, by uniting it, in classification, with those forms which truly resemble it in structure. So also with its physiology. The second question, "How does it live?" would be answered in an exact fashion by the investigation of the life-processes of the animal, and by the knowledge which physiology would bring to bear upon the manner in which kangaroo-existence is divided, like that of all other animals, between supporting its frame, increasing its race, and maintaining relations with the world around.

The question, "Where is it found?" involves in its reply, in the case of the kangaroo, a large number of highly interesting and instructive considerations. Kangaroos are found in Australia and adjacent islands alone. Why are they limited to this region of the earth's surface? and why, to put this question more generally, has Australia no native quadrupeds other than these marsupials and their near relations?—for it need hardly be added that the horse, cow, sheep, and allied animals are all of recent introduction by the hand of enterprising, colonising man. Looking at a zoological map of the world—a chart prepared solely with reference to the distribution of animal life—we should observe that the animals peculiar to Australia stop short on one side of a line called "Wallace's Line," which passes in one part of its course between the little islands of Bali and Lombok in the Eastern Archipelago. The Straits of Lombok are about fifteen miles in width, yet that narrow sea divides the land of marsupials—Australia and adjacent islands—from other lands and islands in which no marsupials are found.

Why, then, should the kangaroos and their marsupial kith and kin stop short at "Wallace's Line"? The answer to this query involves considerations which extend over the whole domain of life-science. The briefest possible explanation of the kangaroos' distribution must therefore suffice for our present purpose. Let us go back in imagination to that far-back time in the history of our earth when the Triassic rocks were being formed. That period existed ages before the Chalk in point of time. It was the period, moreover, when the first quadrupeds appeared on the earth's surface. These primitive animals were wholly of marsupial kind, and entirely of the type of which our kangaroos and other Australian mammals are the existing representatives. Not a single higher mammal thus graced the Triassic forests; no elephants roamed in Triassic jungles; the plains of these early times were unenlivened by the agile deer, or by the grace of the antelope herds; no carnivora roamed about to slay and devour the weaker races; and the humblest quadrupeds were lords of animal creation, and represented in themselves the fulness of the mammalian life which the later ages were destined to see.

Over the whole land surfaces then in existence these low marsupial quadrupeds of the Trias in due course spread. In Britain, on the Continent, in the New World, the fossil remains of these early Triassic quadrupeds are found; the best known of them being represented most nearly by the little "banded ant-eater" (*Myrmecobius*) living in Australia to-day. In the Triassic period, also, Australia obtained its marsupials. For that island-continent was then part of the Asiatic or Palæarctic mainland, and the connecting land was not then broken up into the islands of the Eastern Archipelago of to-day.

The next phase in the drama of Australian quadruped-life shows us that, at the close of the Triassic and of the succeeding Oolitic periods, that land became disjointed from the mainland. Geological change made Australia the island-continent we see it to-day. And what of its quadrupeds? These early marsupials, left to themselves, shut off from all possible invasion by and competition with higher and later quadrupeds, flourished and grew apace in the Australian land. Elsewhere, and in the rest of the world, the early marsupials were distanced in the "struggle for existence" which ensued on the evolution of higher types of life. Elsewhere than in Australia, they were killed off; and at the close of the Oolite age (or that immediately succeeding the Trias) hardly a remnant of the great marsupial life of these two periods was left to bear witness to the first beginnings of mammals on the earth. In Australia how different was, and still is, the quadruped-life! In the "recent" bone-caves of Australia we meet with the remains of giant marsupials, compared with which the largest kangaroo of to-day appears a pigmy form. These are the lineal descendants of the first mammalian population which Australia obtained from the Triassic period. Thus left unopposed, until the advent of the colonists, the marsupials have lived and flourished in Australia, which still retains the main features of its Triassic and Oolitic life. For in its seas swims the Port Jackson shark, elsewhere known only by fossil representatives from the Oolitic rocks. In its rivers lives the curious fish *Ceratodus*, whose teeth occur fossil in Triassic and Oolitic formations. The cycads and araucarias, representing a typical and universal plant vegetation of the Oolitic times, still flourish in Australian soil, though elsewhere scanty or non-existent; and even the shell-fish on the shores of Australia belong to types which flourished in our own Oolitic seas, but which have since practically died out over the world, save the Australian shores. Thus, Australian life of to-day is merely the survival of the general life which prevailed over the world in the Trias and Oolitic periods. The history of the kangaroo points out clearly enough that only on the theory of evolution having given rise to new species from the ancient and original Triassic stock, can we account for the persistence in a corner of our existing world, of the otherwise lost and extinct population of the first quadrupeds.

Lastly, the opossums—which, as a family of marsupials, we should have expected to find in Australia—are discovered, as already remarked, in America. "How came they, then, to inhabit the New World?" is a question worth answering, along with that which inquires into the distribution of the kangaroo. The opossums, firstly, represent a family which never entered Australia. They were plentifully existent in Europe and elsewhere in the Oolitic period; and even nearer our own day—namely, in the Eocene and Miocene formations—the opossums lived in the Old World. These facts are accurately told us by the history of their fossil remains. Thence their range extended to the New World; and, when a subsequent irruption of higher quadrupeds killed off the opossum-race elsewhere, these animals continued to flourish and grow in the New World, presumably because the struggle for existence was and is less severe in the latter region. As the kangaroos are survivals of a quadruped-life, world-wide in Triassic and Oolitic times, so the opossums are survivals in their turn of later marsupials than the Australian animals. Finding in the New World, to which they migrated, a suitable home, the opossums, distanced in the competition in the Old World and now extinct therein, have flourished apace across the sea, and have extended their bounds even into the northern part of the American continent.

The deep water of the narrow "Wallace's Line" between Bali and Lombok, therefore, indicates a channel of great antiquity, which severed Australia from the nearest land, and which, presenting an impassable gulf to migrating forms, has kept the original quadruped-life of that island-continent free, separate, and unmingled with the higher types of life evolved since Triassic and Oolitic times. Thus do we answer the question, "Where is the kangaroo found?"

The remaining question, "How has it come to be what it is?" or, in other words, "How has it assumed its present place in the organic series?" has been answered in greater part by the preceding observations. If the first quadruped population of Australia was, as we know it to have been, of marsupial nature, our existing kangaroo must be the descendant of pre-existing species. Laws of descent, affected by variation, have unquestionably produced and evolved the existing kangaroo from ancestors more or less resembling itself. This much is clear, at least—that although the exact lines of descent and variation of the marsupial families of to-day are as yet undetermined, the great principle of descent through variation from pre-existing species, remains, not a theory merely, but an inferred and unmistakable fact from the circumstances of the case. As the various opossums now inhabiting America are the descendants of the one or more primitive species which first colonised the New World, so the varied marsupial life of Australia is the legitimate outcome, through variation, of the primitive quadrupeds which first peopled that strange land in the old Triassic days. As Professor Flower has remarked, even the likeness between the feet of marsupials is too close to admit of any doubt of their derived relationship, "of inheritance from a common ancestor." And the causes which have produced the striking likeness of this one feature in marsupial history are simply those which have also evolved, from a common origin, the varied features and new offshoots which mark the marsupial life of to-day.

The somewhat extended survey thus taken of the means and methods of biological study obviates any necessity for extending more fully our researches into the remaining characteristics of modern biology. What remains to be said on this latter head may, however, be shortly summed up in the light of previous remarks. Natural history science, as prosecuted of old, was a mere collection of descriptions of species. It was a science in which the search after new species, merely for the sake of adding to the number of known forms, was the paramount aim of the zoologist and botanist. Classifications grew apace; but the relations of one species to another, of group to group, or the general plan upon which the animal world was constructed and organised, were either undreamt of as subjects of study, or were cursorily dismissed from scientific view. We have but to open a volume of natural history lore of the past decade of zoology to realise the truth of this statement. We may readily perceive that attention to outside characters and to the construction of artificial systems of classification represented the chief labours of the biologists of past years. But impelled by the researches of Cuvier, who laid the foundations of morphology, and who clearly mapped out the animal world into four great types—three of which to this day remain much as his genius left them—biology awoke to a new lease of life. Placed in possession of some definite aim in the investigation of animal structure, zoologists began the systematic examination of the great divisions of the animal world which Cuvier had mapped out. Next in order came the era marked by the speculations of Lamarck, in turn succeeded that characterised by the imperishable deductions and suggestions of Darwin. Then was supplied the guiding clue, for want of which zoology and botany had been left to progress in slow and desultory fashion. The impetus given by Darwinism and evolution to biology may be fully appreciated when we reflect that in evolution we perceive the suggestion of a rational purpose in the researches we undertake into the structure, physiology, and distribution of living beings. When we discover that life everywhere exhibits progress, that the development of animals and plants has been a work of progress in the past, that modification proceeds apace even now, and that it is possible to discover the clear plan and method of creation in the forms and development of living things, we may readily appreciate the incentives to research in all directions which the idea of evolution, as the method of nature, has given to the biology of to-day.

Understanding something of the theory of the living universe, the biologist can set himself to work hopefully to unravel many of the so-called mysteries of life. Asking himself regarding every living thing the question, "How has it come to occupy this or that place in nature?" he firstly studies its *development as a clue to its descent and origin.* The modern biologist looks to development, above all else, to teach him the true nature and relationships of animals and plants. If a sea-squirt's development runs in parallel lines to that of the lowest fish, then he naturally concludes that like results in this case follow from similarity of origin, and fishes and sea-squirts become organically connected through community of descent. If a *Sacculina* (existing as a mere parasitic bag of eggs on a hermit crab) passes through essentially the same stages in its development as a shrimp, a water-flea, a barnacle, a crab, and all other crustaceans, he feels bound to believe that these varied forms have sprung from one and the same root-stock. If he finds that a frog in its early life is essentially a fish in structure and physiology, he assumes that he is being taught the descent of the frog-race from aquatic and fish-like ancestors; otherwise, why, he may reasonably ask, should nature trouble herself to develop a fish-stage in the formation and growth of the land-inhabiting frog? If he finds that man's development proceeds along the same lines as those of all other vertebrate animals; if he knows that man, like the fish, has gill-clefts in his neck in early life, which clefts are of no use whatever to their possessor; if he finds that other structures, found permanently in lower animals, have a temporary existence in human development—is he not morally bound to believe that, human development being a moving panorama of lower forms of life, man himself has had his beginning in some pre-existing and lower form? If he finds that it is impossible in early life to distinguish the human embryo from that of other quadrupeds, is he not logically bound to regard such likeness as a proof of man's lowly origin? Such are the queries which the biologist of to-day is forced to face. And when the facts of development are fairly stated, the answer is not for a moment doubtful, if only from the overwhelming conviction that Nature has written her method and way of creation in our evolution, and that it is, or should be, our highest pride and glory to read aright that "strange eventful history."

No less powerfully are the deductions and studies of the modern biologist aided by such considerations as those which deal with *variation* in species as a great fact of life. Formerly, when the fixity of species was deemed a grand fact of biology, the idea that variation might exist was unwillingly entertained, if allowed to have any weight at all. Now, with exact knowledge that variation exists to a greater or less extent in every living species—that change is the law, and fixity in species the exception—we can clearly discern Nature's purport in inaugurating such change, as the preliminary to the formation of new races and species. We know that variation proceeds apace in the existing world of life. We ourselves evolve at large, new "races" of cattle and sheep, of pigeons and dogs and horses; and even if it be fully and freely admitted that the causes of variation are still obscure, there will be found no competent biologist to deny either the reality of the changes in species now proceeding in the world, or the results such changes have wrought in the past.

Subsidiary methods and aids in studying the biology of to-day exist in such subjects as rudimentary organs, homologies, missing links, and the like. If we discover that a whalebone whale, which has no teeth in the adult state, develops, before birth, teeth which never cut the gum and are gradually absorbed, we must either assume that Nature is woefully improvident in developing useless structures, or that these useless teeth have a meaning. If we find that, whilst a horse walks upon the single toe of each foot, it possesses other two rudimentary and useless toes in its "splint bones," the same idea of meaning or no-meaning comes vividly before our minds. Rudimentary organs teach us, like development, valuable lessons concerning the past history of the race which possesses them. The useless teeth of whales represent organs once well developed in the ancestors of our existing toothless cetaceans; and when we find in our horse rudiments of two toes, we expect that that single-toed animal is descended from a three-toed race. Is such an idea probable? may be asked. If we visit Yale College, in America, and observe the array of fossil horses there displayed, we shall be able to trace the evolution of the horse in time, from not only three-toed, but four-toed and five-toed ancestors. There, placed in a graduated series, is the proof that evolution is a stable fact. No "missing links" require to be supplied in the series of Yale College: and those who can maintain, in the face of such an array of testimony, that evolution is an impossibility and development a myth, may be regarded as possessing a hardness of heart against honest conviction, compared with which the Egyptian obstinacy against which Moses declaimed and Aaron battled, is mildness indeed.

Homology, or the "science of likenesses," again, teaches us that when organs are built upon the same type, like the feet of marsupials or the limbs of all vertebrates, from the arm of man to the wing of the bird and the breast-fin of the fish, they must have had a common origin. The true nature of organs and parts in animals and plants is only discoverable after a careful study and comparison of their structure and affinities as declared by homology.

Such are a few of the aids to biological study which the modern naturalist has at his command. Under the light and countenance of evolution, every new fact fits sooner or later into an appropriate niche in the biological fabric. No one fact remains isolated and distinct, as in days of old, but all our knowledge of the past and present of living beings tends to supply us with a rational understanding of their origin and progress towards their existing structure and position in nature.

Evolution thus takes its stand on the rational interpretation of the facts of nature. Its reasonable aspect presents its strongest claim to support: its rational explanation of former mysteries commends it to the unbiassed truth-seeker as the key to the former mysteries and inexplicable problems of the past. Founding its data upon observed facts, the evolution theory holds that the living species of this world are in a state of constant change and variation. It maintains that animals and plants are produced in greater numbers than can obtain the necessaries of life. It postulates, what observation confirms—the operation of a "struggle for existence," in which the weakest forms (which are those that do not vary) go to the wall, whilst the strong (those that do vary) survive. It holds that Nature thus appears to set a premium on variation, that she encourages change in species, and that firstly new varieties, then new races, and lastly new species, are thus produced by the modification of the old.

The theory thus presented, calls to its aid all the facts of biological science. It shows by development, that the way of nature is that of progressing from the general to the special. It notes that extinct forms of life can frequently be shown to be intermediate between living forms, and that "missing links" are capable of being supplied as knowledge grows and as research advances. It correlates outward or physical changes in land and sea with the change in species, and shows how varying conditions of life modify the living form. It enlists, as we have seen, the facts of geographical distribution in its favour, and proves, by an appeal to geology as well, that the modification of life through the changes of land and sea accounts for the otherwise puzzling phenomena viewed in the distribution of living beings over the world's surface. Laying hold of every detail of natural science, this theory of nature has thus wrought a mighty revolution in biology; whilst geology and other sciences have moulded their conceptions on the consistent theory of the universe which evolution lays down. It is the pride and boast of evolution that the avenues to which knowledge leads through this theory of the universe are illimitable—that knowledge may truly "grow from more to more" under its benign influence. And, best of all, whilst science is thus made the handmaid of truth, we also find that the spirit of reverence in face of the facts of nature is also inculcated by the study of development. There is no room for the idea of arbitrary interference with the laws of nature when evolution has fairly asserted its right to be heard. As in the inorganic world around us law reigns supreme, as planets revolve in their cycles with unchanging regularity, so in the world of life there is demonstrated to us the existence of law and ordered sequence which prevails in lowest as in highest spheres of being, which directs the destinies and development of man equally with the movements of the animalcule, and which as fully explains the evolution of a leaf, as it does the formation of a world.

III.

THE CONSTITUTION OF THE ANIMAL AND PLANT KINGDOMS.

THE intelligent foreigner, visiting a country which to him is practically a *terra incognita*, and desirous of acquainting himself as fully as possible with the constitution of the land wherein he intends to sojourn, would contrive, before departing from his native coasts, to gain some adequate idea of the new country itself, its government and laws, its social, political, and religious condition, its geographical and geological features, and its general history in so far as these details were necessary for the comprehension of what he expected to see and hear during his foreign tour. If to the details of its present condition he was able to add information concerning its past—if he could trace its history along the lines of centuries, and discover how this event or that occurrence had tended to mould the country and its constitution into its existing form, his appreciation of the strange land, as presented to his view to-day, would tend to become of still more complete nature. And if, lastly, from his study of the past and present of the foreign territory, he ventured to indulge in any reflections on its possible or probable future, and on its chances of further development or possible decline, such reflections would possess every claim to rank as rational thoughts, deducible from his knowledge of the land as it was and is.

The parallelism between the process of acquiring an adequate knowledge of a foreign state, and that of gaining some idea of the constitution of the worlds of living beings, can readily be shown to be of the closest possible description. The most superficial acquaintance with the study of zoology and botany, if carried out in any fashion worthy the name of a scientific and intellectual exercise, must proceed along lines which follow out in all essential details the pathways whereby we gain an intelligent idea of a foreign land. No study of animals or of plants can be satisfactorily carried out without, at least, a brief preliminary discussion of the constitution of the worlds of life, and without some acquaintance with their mutual relationships and their fundamental characters. In the light of recent researches concerning the "why and wherefore" of the animal and plant kingdoms, such preliminary knowledge becomes not merely of high importance, but of absolutely essential nature. In the days before "evolution" was anything but a name, and ere "Natural Selection" had become a striking reality to the biological mind, such knowledge formed the basis of every study of zoology and botany worthy the name of a scientific investigation. To-day, when the burning questions of biology centre around the evolution of the living universe, and include in their sway and limits the details of the development and structure alike of man and monad, it need hardly be urged that some acquaintance with the general constitution of the animal and plant worlds is absolutely necessary for the intelligent comprehension of all that is interesting in the study of life. If the "making of England," to quote the expressive phraseology of a historical authority, be regarded as at once the summation and foundation of all knowledge of the genesis of the English race, so the fundamental nature of animals and plants and a knowledge of their existing relations may be legitimately viewed as the only sound preparation for a knowledge of the great questions that deal with the becoming and making of living things.

The most cursory survey of the worlds of animal and plant life leaves, as the prevailing impression on the observer's mind, the idea of extraordinary variety and diversity of form, colour, and habitat. From the grand *Sequoia* (or *Wellingtonia*) of California to the humble moss that covers a rock, the grey lichens of the walls, or the minute *Algæ* that colour the pools, there is an endless variety in the ranks of the plant kingdom. No less distinctly is the diversity seen in the hordes of animal life. From the giant quadrupeds that find a home in the tropical jungles, through the teeming life of the waters, to the insect life that everywhere surrounds us, and to the animalcular swarms that find a world in the water-drop, there is to be viewed endless and well-nigh undeterminable variation in every feature of existence. Indeed, so wide is the range of the naturalist's sphere of observation, that one might be readily tempted to believe that, save for the one common belonging and possession of life, there seems no bond of union which may link together the hosts that people the earth. The variety in question tends somewhat to puzzle the uninitiated observer when he attempts to form some adequate ideas regarding the relations of animals to each other, or concerning the bonds that connect the apparently diverse forms of plant life. It is this variety also, which in some degree tends to discourage the popular study of natural history—the apparent hopelessness of overtaking in a human lifetime even a small portion of the inexhaustible fields of research, having its own share in the work of discouragement, and in demonstrating the theoretical vanity of human knowledge. But the student of living nature is destined to find a speedy and satisfactory solution of many of these preliminary difficulties at the very outset of his studies. The first tendency of scientific investigation is to correlate the objects of its research; or in other words, to effect a classification and arrangement of subjects destined for investigation. When the child groups the objects by which he is surrounded into animals, vegetables, and minerals, he is unconsciously laying the foundations of a scientific system; and, in reality, the naturalist simply enlarges the conceptions of the child when he shows that differences, as fundamental in their nature as those the child learns to note, can be determined between the varied tribes of animals and the equally diverse groups of plants.

Prior to the time of Cuvier, naturalists concerned themselves chiefly with the description of the different *species* of animals and plants, and with the determination of the characters whereby one species was distinguished from another. The writings of Linnæus, for example, are largely composed of such descriptions, and if we add to such details, others dealing with the habits and distribution of animals and plants, we shall have completed the enumeration of the chief aims of naturalists in bygone days. The popular zoology and botany of to-day, which do not concern themselves with matters beyond form and the recognition of species or the description of habits, reflect, in a very characteristic and exact fashion, the natural history studies of the past. It should be remembered, however, that the classic naturalists, amongst whom Aristotle stands out conspicuously, dived somewhat more deeply into the history of the animal kingdom than their modern successors. But it may be fairly assumed that the ordinary naturalist, prior to Cuvier's time, concerned himself not so much with the *structure* or *morphology* of living beings as with the description of their external forms, peculiarities, habits, and habitations.

With Cuvier, a new and higher era of natural history study dawned. Linnæus had mapped out the animal world into (1) *Mammalia*, (2) *Aves*, or birds, (3) *Amphibia* (reptiles, frogs, &c.), (4) *Pisces*, or fishes, (5) *Insecta* (insects, spiders, &c.), and (6) *Vermes*, or worms—this latter group being, like that of the Linnæan "Insects," a most heterogeneous division, and including all known and lower forms of animal life, from the "worms" themselves downwards as far literally as the senses could reach. It has well been remarked that such a classification as the foregoing possesses a representative in the vocabulary of well-nigh every language. In this view it might be maintained that a popular conception of a unity of animals underlying their obvious diversity was early formed in the human mind. This is undoubtedly true, since the division of the animal world into beasts, birds, fishes, insects, and worms is a step in the construction of animal "types," to one or other of which any animal may be referred. But the system in question exhibits, after all, but little advance on the classification of childhood; and it serves, moreover, to indicate very cursorily indeed the scientific and further delineation of the animal constitution. Lamarck, whose name is associated with views concerning the transformation and evolution of species, contributed a very decided addition to the knowledge of the constitution of the animal world, when, about the close of last century, he showed that the beasts, birds, reptiles, and fishes, instead of being regarded as distinct and unconnected divisions of animals, might be grouped together to form a large and characteristic division of the kingdom. He pointed out that each and all of these animals, as he knew them, possessed, firstly, a spine or backbone. Within this spine (Fig. 1, A p^1), whereof the skull formed merely a front expansion, the nervous system (n^2) was contained as within a tube; whilst below that system, and contained within the body (p^2) itself (as bounded, say, by the ribs), were the heart (*h*), digestive system (*a*), and other organs. Lamarck, commenting upon this arrangement of parts—which a glance at the carcase of a sheep, as vertically bisected in the butcher's shop, will illustrate—demonstrated that no other animals, save mammals, birds, reptiles, and fishes, possessed such a disposition of their organs. The worm or the insect, for instance, possesses a body (Fig. 1, B) we may legitimately compare with the lower tube (A) of the fish or beast, since neither the worm nor insect has a spine containing a nervous system. Hence Lamarck, taking his chief character from the spine or backbone, composed of separate bones or *vertebræ*, named the beasts, birds, reptiles, and fishes the *Vertebrata*, whilst all other animals became accordingly known as *Invertebrata*.

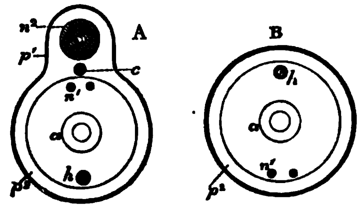


FIG. 1.—CROSS-SECTION OF VERTEBRATE (A) AND INVERTEBRATE (B).

That Lamarck's discovery and his subsequent arrangement of the animal world into these two leading divisions marked a distinct era in zoology no one can doubt. Best of all, his deduction laid the foundation of the method which a little later—that is, about 1795—Cuvier so successfully enunciated and followed out to a practical result. Other hands, in addition, laboured at the scientific edifice, which was practically completed when Cuvier laid before the world his elementary scheme of the history of animals, and showed that at least three *common types* or *plans* could be instituted amongst the *invertebrate* animals. Placed in tabular order, then, the main outlines of the animal world, according to Cuvier, might be thus rendered:—

I. VERTEBRATA ("backboned" animals) (fishes, frogs, reptiles, birds, and mammals).

II. MOLLUSCA ("soft-bodied" animals) (cuttle-fishes and "shell-fish" at large).

III. ARTICULATA ("jointed" animals) (insects, crustaceans, worms, &c.).

IV. RADIATA ("rayed" animals) (star-fishes, corals, jelly-fishes, zoophytes, and all lower animals).

Cuvier's own words, expressive of the nature of these types, may be quoted: "It will be found that there exist four principal forms, four general plans, if it may thus be expressed, on which all animals appear to have been modelled; and the ulterior divisions of which, under whatever title naturalists may have designated them, are merely slight modifications, founded on the development or addition of certain parts." It may be added that the distinguished embryologist Von Baer, attacking the problems of animal form from the standpoint of development, and watching the phases observable in the early history of animals as they advanced from the egg towards their perfect forms, came to the same conclusion as the great French anatomist. According to Von Baer, also, there were four types or plans in the animal world, the distinctive nature of the type to which any given animal belonged being indicated at an early stage in its development. So that, as early as the beginning of the present century, it became clear to the minds of naturalists that, instead of each animal being built up on a type peculiar to itself, it fell into one or other of four groups; in a word, it was found to possess a broad and fundamental plan or type of structure, with which a greater or less number of other animals agreed.

To render the "type" constitution of the animal world plainer and more readily appreciated, we may select one or two examples by way of illustrating, also, how, with the increase of knowledge since Cuvier's days, the original types have remained stable in some respects, whilst they have undergone modifications in others. No two animals can well appear more varied in form, nature, appearance, and habits—and inferentially in structure likewise—than a lobster and a butterfly. The aërial habits of the one contrast very markedly with the slow aquatic life of the other, whilst the general constitution of the former appears to be separated by antipodean differences from that of the other. Are there any bonds of common nature which can link together beings so diverse? and can the butterfly and the lobster be shown to possess any relationships in common? are questions which it is reserved for the scientific but plainly understood deductions of zoology to answer. The superficial examination of the lobster would show that its body consists essentially of a series of some twenty joints, each possessing a pair of appendages modelled, despite their apparent differences, on one and the same plan. So that, although the amalgamated joints of the animal's head and chest (Fig. 2, *ca*) are seemingly different from those of its tail (Fig. 2, 1–6), the zoologist could readily show the uniformity of the series by a comparatively simple dissection, wherein, aided by the knowledge of the animal's development, legs, "nippers," jaws, feelers, and even eye-stalks would be referred to modifications of one and the same type. Furthermore, our dissection of the lobster would show that, whilst its heart (Fig. 3, *n*) lies on its back, its digestive system (*s*, *f*) runs through the middle line of its frame; and its nervous system (*e*, *g*), in the characteristic form of an essentially double chain of nerve-knots, lies on the floor of its body. So that we might diagrammatise with strict accuracy the essential build of a lobster's body by constructing a jointed figure (Fig. 4), wherein the heart (*a*) lay highest, the nervous system (*c*) lowest, and the digestive system (*b*) between the two.

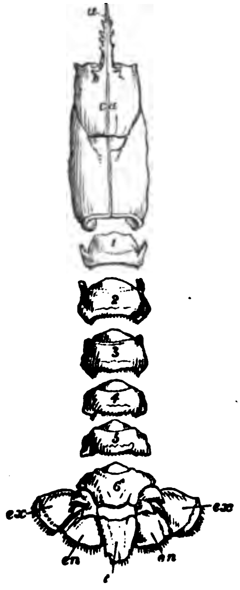


FIG. 2.—JOINTS OF LOBSTER'S BODY.

Now this figure, it may be remarked, would accurately represent every known lobster. It would also stand for the essential structure of every crab—which is merely a tailless lobster—and of every shrimp, barnacle, water-flea, slater, and a host of allied animals as well. Turning now to the butterfly, we should discover from even a rough examination of the insect's frame that it possesses an essentially similar disposition of parts to those of the lobster. The butterfly's heart lies on its back, its digestive system occupies the middle position, and its nervous system lies on the floor of the body, and moreover consists of the same knotted and double chain we see in the lobster. Again, the appendages of the butterfly-body are in pairs, and resemble those of the lobster in all essential particulars, although they are less numerous, in the adult state at least. So that, beyond and beneath all differences in appearance, form, and habits—material as these differences appear

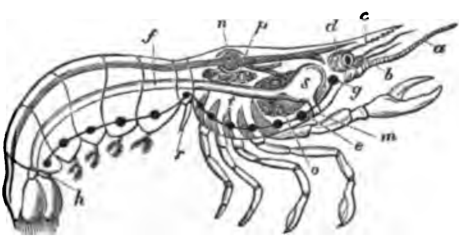


FIG. 3.—DIAGRAM OF LOBSTER'S STRUCTURE.

to be—we discover the great truth that both animals are built up on the same fundamental type. In a word, the ideal diagram (Fig. 4) we have constructed of the lobster's body will serve equally well to indicate the broad features of butterfly-structure. And further, as all crustaceans can be shown to possess bodies modelled on the lobster type, so all insects—numbering many thousands of species—

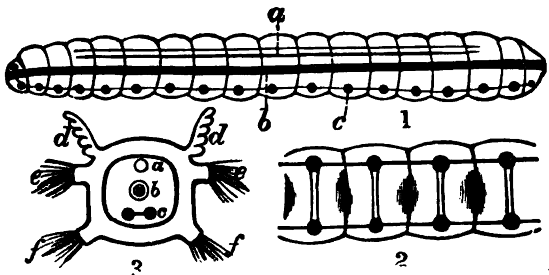


FIG. 4.—DIAGRAM OF AN ANNULOSE ANIMAL.

1. Diagrammatic longitudinal section of *Annulose* animal: *a*, blood or hæmal system; *b*, digestive system; *c*, neural or nervous system. 2. Nervous system of *Annulose* animal, viewed from above, and showing the double ventral nervous chain. 3. Transverse section of *Annulose* animal: *a*, blood system; *b*, digestive system; *c*, nervous system; *d d*, gills or breathing organs; *e e* and *f f*, "oars" or locomotive organs.

may, without exception, be referred to the butterfly type. From which declarations a third may naturally be drawn, namely, that the bodies of all insects and all crustaceans are built up on one and the same fundamental plan. Nor is this all. The diagram (Fig. 3) which, as we have seen, conveys to our mind the essential features in the anatomy of a lobster and a butterfly, and which, through these animals, presents us with a general idea of every insect and every crustacean, can be shown to possess a more extended application still. Every spider, scorpion, and mite agrees with the lobster and insect in its essential structure; and every centipede and millipede likewise has its heart above, its nervous system below, and its digestive system in the middle of its body; whilst if we, lastly, examine the worms themselves, we shall find that our diagram still serves to show the main details of the structure of that extensive class. In this way, therefore, the language of the zoologist becomes clear when he states that all of the foregoing animals constitute "a type of animals." The type in question is, in fact, Cuvier's *Articulata*, or, as it is rendered in modern zoology, that of the *Annulosa*. And there remains yet one important addition to the zoological statement, namely, that no other animals, save the Annulosa or Articulates, exhibit the arrangement of parts just noted. The heart above and the nervous system below (Fig. 4, 1) are characters as distinctive of these animals as is the particular impress on coins of the country or territory from which they were issued.

Yet another illustration may be given of the constitution of animal types by way of impressing their distinctive character on the mind. If we bisect the body of a fish by splitting it through the spine from head to tail, we discover a highly characteristic disposition

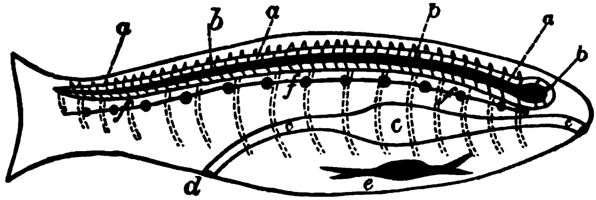


FIG. 5.—SECTION OF VERTEBRATE.

Diagrammatic plan of Vertebrate type. *a a a*, vertebral column or spine, the upper arches of which enclose the brain and spinal cord; *b b b*, "cerebro-spinal" nervous system or axis, consisting of the brain and spinal cord; *c c*, digestive or alimentary system; *d*, anus; *e*, heart; *f f f*, "sympathetic" or "ganglionic" nervous system.

of its organs and parts. Lying along the back, and enclosed within the skull and spine (Fig. 5, *a a*) as within a tube, we find the nervous system (*b b*), consisting of brain and spinal cord. Lowest down, and lying on the floor of the body, is the heart (*e*); above the heart and in the middle position is the digestive system (*c*); and above this system in turn is a second nervous system, distinct from the brain and spinal cord, and known as the *sympathetic system* (*f f*). Thus the positions of organs in the fish, with the exception of the digestive system, are exactly reversed from those of the lobster and butterfly; whilst in that its chief nervous system (*b*, *b*) is enclosed within the bony tube formed by skull and spine (*a*, *a*), the fish presents a most material difference from both animals. Furthermore, we should find that the "fins" of the fish which represent the limbs of higher animals are never more than four in number, and that they are disposed in pairs. A simple diagram, then, might be constructed of the fish (Fig. 5), showing the positions of the various systems as just narrated, whilst a similar idea of vertebrate structure is afforded by the cross-section in Fig. 1, A; and such a diagram would hold true

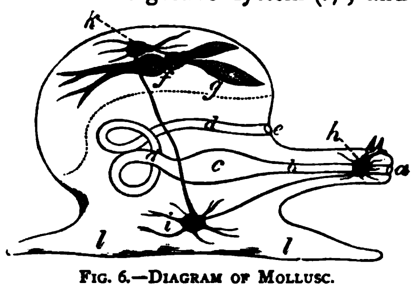


FIG. 6.—DIAGRAM OF MOLLUSC.

for every known fish, just as the diagram of the jointed animal, constructed from the details of the lobster, served to represent the essential anatomy of every known crustacean.

If, now, we examine the structure of a frog or other amphibian, or that of any reptile, we shall find that, like the fish, these animals have a nervous system lying along the back, and enclosed within a bony tube. Again, their hearts are lowest, their digestive system

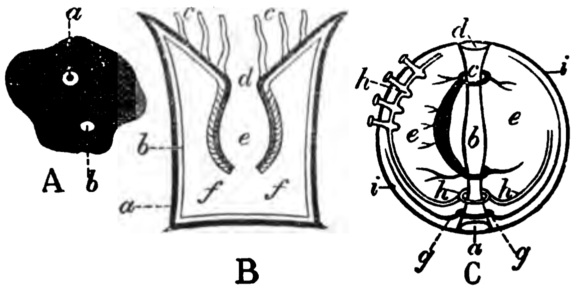


FIG. 7.—DIAGRAM OF ECHINODERM, CŒLENTERATE, AND PROTOZOON.

occupies the median position, and their limbs are never more than four, and are invariably developed in pairs. Hence the diagram of the fish represents the essential anatomy of other two distinct classes, namely, frogs and reptiles. But it is easy to show that the fish type is also represented in animals still more widely removed from all

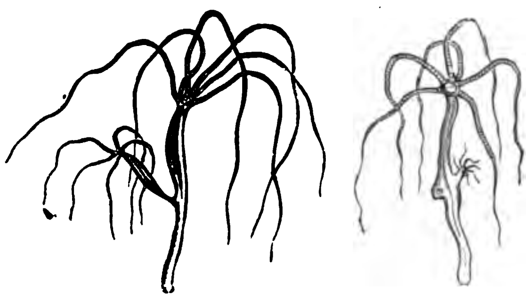


FIG. 8.—HYDRÆ.

apparent relationship with the finny tribes. Between a bird and a fish there seems at first to be no relationship, absolute or comparative; yet the diagram of the fish will serve to express all the structural features of the bird. The latter exhibits, in short, the same arrangement of its nervous, digestive, and blood systems as does the fish; its nervous system is similarly protected by a bony axis; and its limbs are likewise in pairs. And ascending, last of all, to the highest confines of the animal world, and entering into the domain of the quadrupeds or mammals, at the head of which latter group stands the human subject, we find the type of fish, frog, reptile, and bird to be accurately adhered to as the fundamental plan of the quadruped

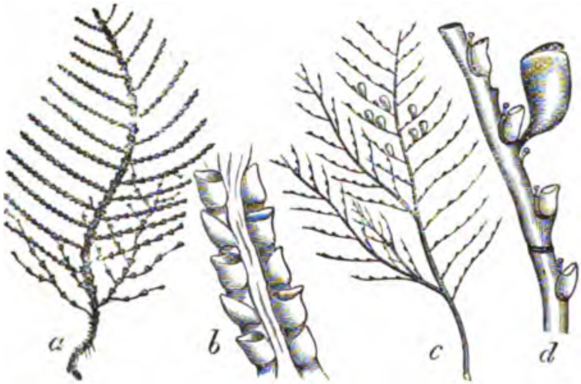


FIG. 9.—ZOOPHYTES
(*b* and *d* represent portions of *a* and *c*, magnified).

body itself; so that the diagram of the fish may be left to express accurately and truly the broad outlines of human anatomy. In this way we discover that a type of animals—the *Vertebrata*—first outlined by Lamarck, as already noted, can be constructed on precisely the same lines, and for the same structural reasons that made the constitution of the *Articulate* type a reality of living nature. Fishes, frogs, reptiles, birds, and quadrupeds or mammals, including man, thus possess bodies constructed on the same fundamental type or plan.

FIG. 10.—JELLY-FISH.

To continue the illustration of the formation of natural groups or "types" of animal life through the discovery of broad or fundamental correspondence in the structure of the body, were an easy matter. It may readily be shown that all ordinary shell-fish—such as the oysters, cockles, snails, whelks—along with the sea-butterflies (*Pteropoda*), and the cuttle-fishes—form another well-marked type, distinguished by the peculiar disposition of the nervous system in three great masses (Fig. 6, *h*, *i*, *k*), as well as by other definite characters writ large enough in the textbooks of zoology. These animals form the type of the *Mollusca*—a group from which many animals therein included by Cuvier have been weeded out to form other divisions, or to find a place in other types. Similarly, the fact that the star-fishes, sea-urchins, sea-lilies, sea-cucumbers, and the like, form another and distinct type (*Echinodermata*), distinguished by the "radiate" shape of the body, and by other characters, might be dwelt upon. A diagram of the star-fish type is shown in Fig. 7, C. It would merely extend our illustrations to show how the hydras (Fig. 8), zoophytes (Fig. 9), jelly-fishes (Fig. 10), corals, and sea-anemones form another "type" (*Cœlenterata*), noted for its curious digestive system (Fig. 7, B *e*), which communicates freely with the internal cavity of the body (B *f*). Whilst, last and lowest of all, the *Protozoa*, represented by the sponges, *Amœbæ* (Fig. 11), the Foraminifera or chalk-animalcules (Fig. 12), and many other and equally simple forms of animal life, constitute the lowest type. These animals are distinguished rather by their want of organs and tissues than by the possession of the belongings of higher animals, and exhibit bodies which consist, for the most part, of simple masses of *protoplasm*, but which, nevertheless, exhibit all the fundamental characteristics of living organisms. The diagram of a Protozoön might thus be adequately enough rendered by a simple figure representing an indefinite mass of protoplasm, such as is represented in Fig. 7, A. It will thus be seen that the four Cuvierian "types" have become largely extended and modified by modern research. But, notwithstanding these modifications, the principles whereon that great anatomist laid the foundations of the constitution of the animal world, remain solid and enduring as of old. If to-day our list of types is of a more extensive character than was the Cuvierian *répertoire*, it must be borne in mind that such a result was in-

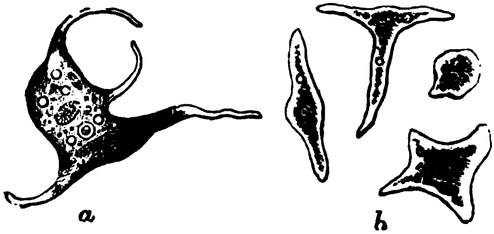


FIG. 11.—AMŒBÆ.
a, *Amœba radiosa*; *b*, *Amœba diffluens*, in various stages of contraction.

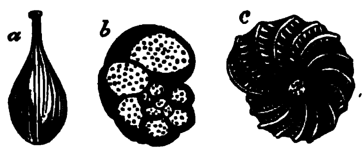
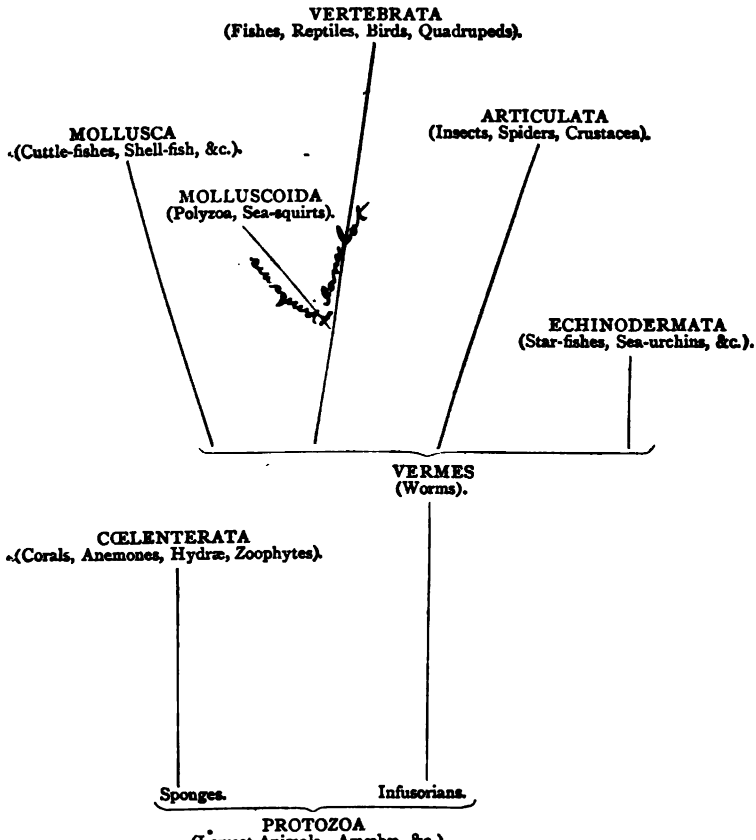


FIG. 12.—FORAMINIFERA.

evitable from the improvement of the ways and means of scientific research. What remains to be effected in biological research, is the enlargement and extension of the types themselves—an increase of knowledge which has, indeed, been carried out along the very lines which led Cuvier to those remarkable generalisations that have formed the basis of modern natural history studies.

Although naturalists are by no means agreed concerning the exact number and relationship of the "types" represented in the animal world; the following table may serve to show the fundamental divisions of the animal kingdom as expressed in modern systems of zoological classification.



Having thus endeavoured to show the chief types of animal life, we may now glance at the conclusions bearing upon the constitution of the animal world to which our researches may legitimately be presumed to lead. It thus seems clear, so far as our studies have led us, that the constitution of the animal world is one in which the development of its included units has followed a series of definite plans or types, leading to the construction of the six or seven primary groups into which the naturalist is accustomed to divide the hosts of animal life. These "types," it must further be noted, are not in any sense theoretical groups, but are founded, as we have seen, on exact and fundamental likenesses in structure. Nor must we lose sight of the exact meaning of the word "fundamental" as thus employed. The use of this term implies that the likeness and similarity in the plan admits of variation in the carrying out of its details. The lobster and the butterfly, for example, are fundamentally alike; their bodies are constructed on an essentially similar plan; and the positions of their organs are identical. But whilst these are fundamental likenesses, they do not imply that of necessity the two bodies should be similar throughout. The tissues of a butterfly may be more complex than those of a lobster, or *vice versâ*; just as the heart or brain of a frog is a more complex organ than that of a fish, and as each organ of a bird or a man shows, in turn, an advance upon that of the frog. The variations, however, are all more or less plain and evident elaborations of one type. As Cuvier put it, "the ulterior divisions" of each type, or, in other words, its arrangement into subordinate groups, drawn upon differences in the included animals, are founded upon "slight modifications" of the type, or by "the development or addition of certain parts"—which parts, it may be added, can, as a rule, be shown to be represented in one form or another in the original constitution of the type.

A second consideration of importance in discussing the constitution of the animal world consists in the emphatic declaration of the modern naturalist that it is impossible to arrange animals in a linear series, beginning with the lowest form and ending with man. The nature of the constitution of the animal world, in short, does not admit of any such arrangement; since it would be manifestly impossible to determine in very many instances which, of two animals or of two groups, should be ranked the higher. It would be a puzzling, if not an impossible task for any naturalist to determine, for example, whether a cockroach or a cuttle-fish should be ranked highest in the scale. The fact that the body of the one is constructed on an utterly different type from that of the other, constitutes a primary difficulty of no mean order; and there intervenes a second consideration, namely, that of the impossibility of settling any standard whereby the organisation of the one might be legitimately compared with that of the other. As Professor Huxley has graphically remarked, "regarded as machines for doing certain kinds of work, animals differ from one another in the extent to which this work is subdivided. Each subordinate group of actions or *functions* is allotted to a particular portion of the body, which thus becomes the organ of those functions; and the extent to which this division of physiological labour is carried differs in degree within the limits of each common plan, and is the chief cause of the diversity in the working out of the common plan of a group exhibited by its members. Moreover, there are certain types which never attain the same degree of physiological perfection as others do." These words indicate clearly enough that the high or low character of any animal in a type, depends chiefly upon the complexity of the functions, and necessarily of the organs, whereby life is maintained. As the household whereof the labour is performed by a maid-of-all-work, is functionally less complex than that whose work is performed by a retinue of servants, each discharging a special duty, so in the animal world, the rank of any one of its members or of its groups can only be determined by the complexity of body, and by the corresponding degree of intricacy with which the functions of the body are performed. Furthermore, it is the development of this complexity, or the reverse, from the common plan, which, as Huxley has so well expressed it, is the actual cause of the variations we see in each type. The frog is not higher than the fish because of its type—since both exhibit the same fundamental plan; but because the frog's functions are more specialised—there is a more minute physiological "division of labour" in the frog, and there exists a more complex staff of organs (developed from the common plan of fish and frog) to discharge the increased work. Of the differences between a frog and a bird, and between both and a man, precisely the same remark may be made. The higher or more complex life involves and demands from the common type, the more complex frame.

To quote Professor Huxley's words once more, "a mill with ten pairs of mill-stones need not be a more complicated machine than a mill with one pair; but if a mill have two pairs of mill-stones, one for coarse and one for fine grinding, so arranged that the substance ground passes from one to the other, then it is a more complicated machine—a machine of higher order—than that with ten pairs of similar grindstones. In other words, it is not mere multiplication of organs which constitutes physiological differentiation; but the multiplication of different organs for different functions in the first place, and the degree in which they are co-ordinated, so as to work to a common end, in the second place. Thus a lobster is a higher animal, from a physiological point of view, than a *Cyclops* (or water-flea), not because it has more distinguishable organs, but because these organs are so modified as to perform a much greater variety of functions, while they are all co-ordinated towards the maintenance of the animal by its well-developed nervous system and sense organs. But," concludes Huxley, "it is impossible to say that, *e.g.*, the *Arthropoda* (insects, spiders, centipedes, &c.) as a whole are physiologically higher than the *Mollusca* (shell-fish and cuttle-fishes), inasmuch as the simplest embodiments of the common plan of the Arthropoda are less differentiated physiologically than the great majority of Mollusks."

Whilst the difficulties which lie in the way of determining the higher or lower rank of many organisms are thus apparent, it may be remarked that the means already specified — namely, the physiological perfection of the animal—may in turn assist us in assigning to many forms their relative place in any type or group. Thus the possession of air-breathing organs, or *lungs*, is admittedly a mark of a higher organisation than that which possesses *gills*; the life of the air-breather being, as a matter of fact, associated with a structural perfection excelling that of the aquatic and gill-bearing animal. So also the degradation of organs and parts which accompanies *parasitism*, naturally lowers an animal in the series as compared with its non-parasitic neighbours. Thus within the limits of any one type of animals, we may discover many examples of tendencies to higher as well as to lower development, these tendencies determining the position of the organism within its own type, and either elevating itself or its group collectively, or, on the other hand, degrading it, and assigning it to a low place in the type. The impossibility of any scientific or natural arrangement of animals in a linear series can thus be shown to depend simply upon the constitution of the animal kingdom as a whole. If any arrangement of the great types it presents to view is permissible—and naturalists are agreed that some such relationship is embodied and included in the constitution of the kingdom—such an arrangement will find its clearest expression in the metaphor of a tree. As represented, indeed, in the foregoing table (page 47), the various types may be regarded as the great branches of the animal tree, rising here and there from a common stem or root, and developing, each along its own special line and type, into the variety and fulness of form exhibited before our eyes to-day.

The impression which is liable to be left on the mind of the observer who, thus far, has traced out the constitution of the animal world into its fundamental types or plans, will undoubtedly take the form of the idea that the mere existence of these types or plans as we behold them represented in living animals would appear to indicate the separate and disconnected nature of the great groups in question. Considerations of this nature inevitably lead to others, dealing with the origin of these plans of animal life; and the conclusion that these types have each had an independent origin might seem, at first sight, to possess actual warranty for acceptation and belief. But a fuller consideration of the constitution of the animal world will tend to dispel any such tacit agreement concerning the actual independence and distinctness, or regarding the separate origin of the animal types already noted. On the contrary, a deeper acquaintance with facts as they stand, will inevitably tend to show us, firstly, that the limits of the types are by no means so rigidly circumscribed as the older naturalists supposed. Whilst, secondly, we may discover that evidence exists to show, not merely that the various types are by no means sharply demarcated from each other, but that in the nature of things they exhibit relationships of the highest importance in the attempt to discover the exact nature and constitution of the animal world.

With regard to these latter contentions it is easy to show, for example, that the great "types" of animal life, whilst remaining distinct enough to constitute divisions of utility in classifying animals, nevertheless often merge into one another, and become connected by "intermediate forms"—that is, are linked together by animals or by groups which may be termed "transitional" in every respect. If the existence of such links between any of these types be proved, the distinct and utterly separated character of all may logically be denied. The fact that the types are connected in any fashion, must also be held as showing that some form of progression from one to the other must be postulated as an essential part and feature of the animal constitution. In other words, we are led to believe in the continuity of these types, as opposed to the idea of their separate origin. We are led to espouse the idea of an uninterrupted development, as opposed to that of the separate and independent origin of the great plans of animal structure. It is interesting, however, in the first place, to find that there is an unmistakable reflection of such a continuous development to be discovered within the limits of each type; and to this latter aspect, or that concerning the types themselves, it may now be well to direct our attention.

If we select any type, from the lowest to the highest, we may readily discover that its included animals exhibit amongst themselves a connected relationship such as the mere fact of their bodies being built upon one and the same plan would of itself be sufficient to suggest. Amongst the *Articulate* animals, for instance, this relationship is plainly seen; and it is no less evident amongst the *Vertebrates* and *Molluscs*, as will be more plainly shown in succeeding chapters. Why, it may be asked, should the segments or joints of the lobster's body (Fig. 2) and of the insect frame be constructed on one and the same plan? Or, again, why should the appendages of the bodies of these animals, which resemble each other far more closely in the early stages than in the adults, present a striking correspondence of type that is only marked by the modifications they undergo through adaptation to varied ends? Why, again, should the mouth-parts of a butterfly, adapted, as every one knows, for suction, be formed of essentially similar and corresponding parts to those which are found in the biting mouth of a beetle? And why should the arm of man, the wing of the bird or bat, the fore-limb of the horse, the paddle of the whale or dolphin, and the fore-limb of the frog, as will be more fully shown in a future chapter, be constructed on one and the same type?

The answer to these pertinent inquiries can only be found in some conception which demands and postulates some intelligible relationship between the varied and yet fundamentally similar parts. Mr. Spencer, speaking of similar facts in the structure of Articulate animals, asks, "What, now, can be the meaning of this community of structure among these hundreds of thousands of species filling the air, burrowing in the earth, swimming in the water, creeping about among the seaweed, and having such enormous differences of size, outline, and substance, as that no community would be suspected between them? Why under the down-covered body of the moth, and under the hard wing-cases of the beetle, should there be discovered the same number of divisions as in the calcareous framework of the lobster? It cannot be by *chance*," continues Mr. Spencer, "that there exist just twenty segments in all these hundreds of thousands of species. There is no reason to think that it was *necessary*, in the sense that no other number would have made a possible organism. And to say that it is the result of *design*—to say that the Creator followed this pattern throughout, merely for the purpose of maintaining the pattern—is to assign a motive which, if avowed by a human being, we should call whimsical. No rational interpretation of this and hosts of like morphological truths, can be given except by the hypothesis of evolution; and from the hypothesis of evolution they are corollaries. If organic forms have arisen from common stocks by perpetual divergences and redivergences—if they have continued to inherit, more or less clearly, the characters of ancestral races; then there will naturally result these communities of fundamental structure among extensive assemblages of creatures that have severally become modified in countless ways and degrees, in adaptation to their respective modes of life." Choosing thus the doctrine of evolution, we can clearly enough account for the general likeness exhibited by the various members of an animal type. The animals of each type resemble each other because they are descended from a common stock. "Descent with modification" is the key which unlocks whatever mysteries hedge about the fundamental likeness we see in each type of animal life.

In a future chapter we shall endeavour to trace the evidence which has already been gathered in favour of the accumulation of transitional forms, between the main divisions of the vertebrate type, as illustrative of "missing links" at large. In the present instance we may sum up the testimony which tends to support and prove the biological declaration that, between the types themselves, there exist intermediate forms, the presence of which tends to substitute the idea of the gradual and continuous nature of animal development as opposed to that of interrupted or "special creations." For example, it is a comparatively easy matter to demonstrate that the gulf between Vertebrate animals and their Invertebrate neighbours has been largely bridged over, so that to-day no competent naturalist doubts the connection of the highest type of animal life with lower forms. The evidence of such a connection will be more fully detailed hereafter, but it is permissible to refer to its main details in the present instance. The Vertebrate animals have already been shown to be those which alone possess a spine enclosing the nervous system, and which, moreover, of all animals, are those having the heart lowest, and possessing never more than four limbs, these latter appendages being developed in pairs. But when we pass to the lower confines of this group, we discover that the lowest fish (the lancelet [or *Amphioxus*], Fig. 13) presents us with a clear-bodied organism, attaining a length of only an inch or two, and destitute of nearly all the special belongings of the fishes themselves. In place of a spine and skeleton, it possesses a soft cellular rod (the *notochord*), such as every other vertebrate develops in early life, but which in all, save a few fishes, is replaced by the backbone. It breathes by an enlargement of the throat; its nervous system, lying upon the "notochord," is a mere nervous cord destitute of a brain; its eyes are mere specks of colour; and it wants a heart, kidneys, spleen, and also the sympathetic nervous system found in all other vertebrates. When, therefore, we attempt to place the lancelet in an animal type, we are met by the difficulty that whilst, in the possession of certain important characters, it is undoubtedly a vertebrate, in the want of other characters it appears to lie outside that type. Again, we discover an equally important fact when we learn that

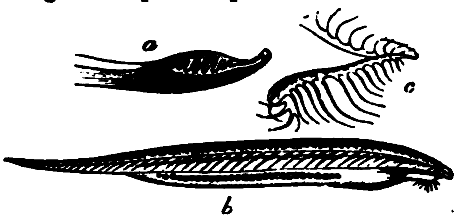


FIG. 13.—LANCELET.
a, head; *b*, the fish viewed from the side; *c*, filaments surrounding the mouth.

the lancelet presents distinct affinities with the sea-squirts (Fig. 14), or *Tunicates*, which belong to the molluscoid type (*see* table, page 47), and the commoner species of which may be compared each to a veritable bag, or "leather bottel," firmly attached to rocks, shells, and like objects. These likenesses, to be more fully discussed hereafter (*see* Chapter IX.), are seen, not merely when the structure of the adult sea-squirt and lancelet are compared, but are still more clearly discernible when the development of the two animals is studied. The lancelet, in short, resembles a fish, or lower vertebrate, whose development has been arrested, so to speak; and it is equally interesting to discover that there exist certain sea-squirts which, in their special features, approach very nearly to the lancelet, and in which the "notochord"—long supposed to be the special possession of the young of vertebrate animals—remains, as in the lancelet, persistent throughout life. Thus the lancelet remains before us, constituting, in every sense of the term, a link between vertebrates and invertebrates. It agrees wholly neither with the highest type nor with the molluscoids or sea-squirts themselves, but exhibits a series of characters strictly intermediate between the two types. We may readily enough understand, on these grounds, why this little clear-bodied animal, which at first was regarded as a worm, and then as a kind of slug, should, from the peculiarity of its position as the apparent root of the vertebrate type, have been styled, "next to man, the most important vertebrate."

FIG. 14.—SEA-SQUIRT.

As Professor Huxley has pertinently remarked, "in 1859 there appeared to be a very sharp and clear hiatus between vertebrated and invertebrated animals, not only in their structure, but, what was more important, in their development. I do not think that we even yet know the precise links of connection between the two; but the investigations of Kowalewsky and others upon the development of *Amphioxus* and the *Tunicata* prove, beyond a doubt, that the differences which were supposed to constitute a barrier between the two are non-existent. There is no longer any difficulty in understanding how the vertebrate type may have arisen from the invertebrate, though the full proof of the manner in which the transition was actually effected may still be lacking." For these weighty reasons, the vertebrate type, in the tabular view of the types of animal life (page 47), is represented as having its root laid within the sea-squirt or "tunicate" line of descent.

If at random we selected other types of animal life, we should similarly discover that they exhibit more or less distinct relationships with other divisions or plans of the kingdom. The molluscoids or "sea-squirts" themselves, for example, appear to be related, through a curious worm-like creature, named *Balanoglossus*, to the worms on the one hand, and to the star-fish group (*Echinodermata*) on the other. Or, if we select the last-named group itself, we may discover that the star-fishes and sea-urchins are not more isolated from other types than are the vertebrates. The star-fishes, in fact, present many points of affinity to certain worm-like forms; and their development, to be hereafter alluded to, clearly relates them, in the eyes of the naturalists, to lower types of animal life. Again, the lowest animals, or *Protozoa*, appear to be linked to the *Cœlenterate* type (or that of the zoophytes, corals, sea-anemones, &c.) through the sponges, which unite, in a most characteristic fashion, the features of the lowest forms with organisms of a higher grade. And, lastly, as amongst the worms we find the roots of the star-fish type, so in that class also we discover the beginnings of the great *Articulate* plan, which possesses the insects, crustaceans, and allied animals as its chief representatives. As has well been remarked, "it may reasonably be doubted whether any form of animal life remains to be discovered which will not be found to accord with one or other of the common plans now known. But, at the same time, this increase of knowledge has abolished the broad lines of demarcation which formerly appeared to separate one common plan from another."

Lastly, it will be shown in future chapters that the various animal types start in their development from a common basis, and agree in the earlier and essential stages of their progress towards their adult forms. There is a literally amazing likeness to be discerned between the early stages of the development of many animals which, as adults, and as belonging to different types, present not the slightest resemblances to one another. Each animal, in fact, traced backwards in its history, "approaches the earlier stages of all the rest;" that is to say, "all start from a common morphological type, and, even in their extremest divergence, retain traces of their primitive unity." Such unity will form the special subject of the succeeding chapter, when the common and universal matter of life, or protoplasm, is discussed in detail.

It may thus be demonstrated as a fact, and as a matter removed entirely from the domain of theory and hypothesis, that, whilst the great world of animal life exhibits a constitution, in the study of which its component elements are seen to be resolvable into several distinct "types" or "plans" of structure, the development of these types has followed a pathway and progress comparable to the growth of a tree. The connections between types and the existence of intermediate and transitional groups of animals, apparently belonging to one type when studied from one aspect, but exhibiting the closest alliance with another type or plan when different details of structure are regarded, prove in the clearest fashion that continuous development has been the "way of life" in the animal world. Whilst, lastly, the bare fact that, as we trace the histories of all the types backward towards their early life, the likeness grows in exactitude until it merges in absolute identity, constitutes in itself a detail which is all-eloquent in favour of the idea that only on one theory can the entire constitution of the animal world be explained. That idea, it is needless to remark, is embodied in the theory of evolution, which postulates descent from a common root or stock with subsequent modification as the only satisfactory explanation of the constitution of the animal world.

The constitution of the plant world may be briefly alluded to, by way of close to these observations, because the issues of botanical science tend to support, in the plainest fashion, the deductions and generalisations just detailed concerning the origin of the types of animal life. The variety of plant life is not less profuse than the diversity presented by the tribes of animals; but, like their neighbour organismis, the plants exhibit certain broad types, to one or other of which it is possible to refer any single plant or group. If a table of the plant-types be constructed, it will assume such a form as that indicated :—

These plants are composed of cells only.	I. THALLOPHYTES (*e.g.* *Algæ* (or Seaweeds, &c.) and *Fungi*). II. MUSCINEÆ (*e.g.* Liverworts and Mosses).		These constitute the *Cryptogams*, or flowerless plants.
Plants composed of cells and vessels.	III. PTERIDOPHYTES (*e.g.* Ferns, Horsetails, Club-mosses).		
	IV. PHANEROGAMS (higher plants):	A. GYMNOSPERMS, or those having no seed-vessels (*e.g.* Firs, Pines, &c.). B. ANGIOSPERMS, or those having distinct seed-vessels : (*a*) Monocotyledons (*e.g.* Palm, Lily). (*b*) Dicotyledons (*e.g.* Oak, Primrose, &c.).	These constitute the *Phanerogams*, or flowering plants.

Discarding all botanical technicalities, save those absolutely necessary, the types of plant life may be readily enough appreciated. If we examine such a plant as an oak, a primrose, a buttercup, a palm, a lily, or, indeed, any ordinary member of the plant series, we may discover that it possesses conspicuous *flowers*, and that accordingly it may be distinguished from such plants as the ferns, mosses, and fungi, in which no flowers are developed. Such a state of matters suffices, along with other and equally distinctive points of structure, to separate the higher plants (or *Phanerogams*) from the lower or flowerless plants (*Cryptogams*). But, selecting the flowering and higher plants themselves, we may readily discover that certain highly distinct types are represented within their limits. Thus, when we watch the development of an oak, a bean (Fig. 15), a primrose, or a buttercup, for example, we discover that the young plant develops or possesses two primitive leaves, named "seed-leaves"—the *cotyledons* (*c*) of the botanist (Fig. 15). Again, such plants have their flower-parts arranged in fours or fives; and, whilst their stems grow outwards, the leaves present us with the network of veins (Fig. 16) so well seen in "skeleton leaves." These characters suffice to group the highest plants into a type known as that of the *Dicotyledons*.

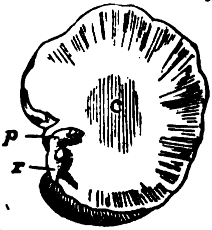


FIG. 15.—BEAN IN SECTION. *c*, one of the cotyledons; *p*, young stem; *r*, the young root.

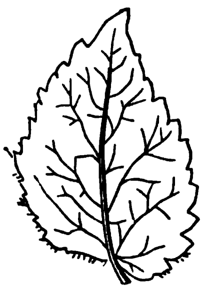


FIG. 16.—LEAF OF DEAD-NETTLE.

If now we examine a palm, a lily, a tulip (Fig. 17), or a hyacinth, we shall find that only one "cotyledon" or "seed-leaf" is developed by the young plant. Furthermore, the leaves have parallel veins—a conformation well illustrated in the tulip leaf (Fig. 18) and the onion leaf, for example. Again, the stem of these plants is an "inward-growing" structure, and the parts of the flowers are developed in threes or in multiples of that number. Hence a second type of plants is constituted by the palms, grasses, lilies, and their allies, and to this type the name of *Monocotyledons* is applied.

A third type of plants is also included in the group of "flowering plants." This latter type is constituted by the conifers, or "cone-bearing" plants—such as the larches, firs, cedars, cycads, araucarias, cypresses, junipers, &c.—and presents in many respects clear evidence of its title to be regarded as a highly distinctive and specialised group of plants. The chief characters of these plants consist in the peculiarity of their flowering arrangements, which are represented in the well-known "cones." Again, the seeds are not contained within a seed-vessel, as in ordinary plants (*e.g.* pea), but are borne on the cones.

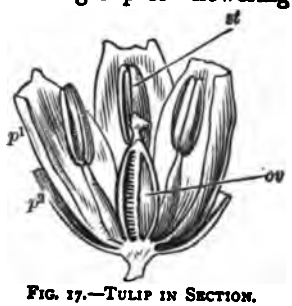


FIG. 17.—TULIP IN SECTION.

Hence arises the technical name of *Gymnosperms* ("naked-seeded"), applied to the pines, firs, and their allies.

The foregoing types constitute collectively the "Flowering" plants of the botanist. Ranking below these plants, however, is a number of types containing plant-organisms of highly characteristic nature. Thus the Ferns, Horsetails (*Equisetæ*), and Club-mosses or *Lycopods*, form one section of the "Flowerless" plants. In these forms the true plant arises not directly from a seed, as in the higher orders of plant-life, but from a curious leaf-like structure called a *prothallus*, which in its turn arises from the *spore* or germ of the parent plant. Thus from the spore of a fern, falling from the back of its frond, springs the leaf-like "prothallus." On the under surface of this body are developed organs giving rise in turn to the young fern, which is thus developed intermediately and indirectly from its parent. This character, united with others, which need not be specified here, serves to render the fern type clear and individualised. It may be added, however, that the stem in such plants grows chiefly at its summit, and that its leaves or "fronds," which bear the reproductive organs, exhibit a forked arrangement of their veins.

FIG. 18. LEAF OF TULIP.

Equally "flowerless" with the ferns and their neighbours are plants which, however, rank below these well-known forms in the botanical scale. Thus the *Muscineæ*, or Mosses and Liverworts, appear as a distinct type of lower plants which are composed solely of "cells," and which do not possess true "roots" comparable with those of higher plants. And in the lowest of the plant world we meet with the Seaweeds, Fungi, and a host of microscopic plants, equally "flowerless," equally cellular in composition, and which, moreover, do not develop the stem and leaves of the mosses. Many of these lower plants are represented by single "cells;" the well-known *Diatoms*, the Yeast Plant (Fig. 19), and many others illustrating such a constitution; whilst a mushroom or other fungus is simply a mass of cells, and nothing more.

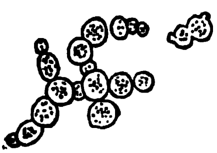


FIG. 19.—YEAST PLANTS.

These details prove that the plant world exhibits a constitution in which "types" appear as prominently as in the animal kingdom. Furthermore, it can readily be shown that the plant types are not more distinctly separated from one another than are those of the animal world. It is demonstrable, for instance, that the *Algæ* or Seaweeds are connected by intermediate forms with the

Lichens and Fungi; whilst no botanist questions the idea that the ferns, club-mosses, and their neighbours, lead the way from the lower or "flowerless" plants to the *Gymnosperms* (or firs, pines, &c.) amongst the "flowering" plants. Between the Monocotyledons and Dicotyledons, again, there are obvious links, and hence we discover that the whole plant kingdom may be regarded as being bound together after the actual fashion of its own product seen in the tree, which, whilst possessing its individual parts, likewise exhibits a continuity of development that forms one of the chief characteristics alike of the single organism, and of its relationship with its neighbours.

In the lowest deeps of plant life we may discover organisms which possess at the best a doubtful title to be regarded as the objects of botanical study. In the animal world, likewise, are included lower organisms which may be regarded in certain aspects as possessing true relationships with plants. Modern biology to-day frankly admits its inability to pronounce whether certain lowest forms of life are animals or plants. Certain "monads," for example, consisting each of a speck of protoplasm provided with the microscopic whip-tails, exhibit a highly confusing identity of structure and function, which renders their exact nature indeterminable, or at least highly doubtful. Hence we discover that apparently at the lowest confines of the animal and plant realms we enter a "biological 'No man's land,'" whereof the included inhabitants may legitimately claim relationship with both kingdoms. They exhibit in this latter respect, in the eyes of the biologist, the actual survivals of that early epoch in the history of life's development when the specialised kingdoms of animals and plants were not, and when existence passed placidly along the common lines which were soon to diverge into the two great series of living beings that environ our footsteps to-day.

The great lesson which a study of the constitution of the living worlds is calculated to teach the independent observer may be summed up in the contention that the entire subject testifies to the continuous and connected nature of the development of life at large. The beginnings of higher and lower life alike, are represented by humble stages, wherein specks of protoplasm, or at the most simple "cells," discharge all the functions of existence. From such simple beginnings the highest being is developed. The difference between the highest and lowest organism is therefore not so much one of kind as of the degree of perfection to which elaboration and development has carried the living form. We may be unable definitely to indicate why one organism speeds along this pathway to assume a place in one type, or why another, apparently identical in its early life with the first, should develop into a widely different being, But beyond such questions lies the biological surety that to understand the way of the becoming of both animal and plant is to deny any independence of creation, and to assert that unless the phenomena of life be without meaning, all nature testifies to continuous development as the main feature of the living constitution. To collate the evidence which widely different branches of inquiry supply in favour of this view, is the chief aim of the succeeding chapters. But Mr. Spencer's words may be once again quoted by way of showing succinctly and plainly the general conclusion of the present study. "The general truths of morphology," says Spencer, "thus coincide in their implications. Unity of type maintained under extreme dissimilarities of form and mode of life, is explicable as resulting from descent with modification; but is otherwise inexplicable. The likeness disguised by unlikenesses, which the comparative anatomist discovers between various organs in the same organism, are worse than meaningless if it be supposed that organisms were severally framed as we now see them; but they fit in quite harmoniously with the belief that each kind of organism is a product of accumulated modifications upon modifications."

IV.

CONCERNING PROTOPLASM.

THE nature of that curious collocation of actions we commonly denominate "life," and the connection which exists between life and the bodies it invests and whose interests it directs, have ever formed subjects of extreme speculative interest to cultured mankind. In the classic ages such speculation was rife, and modern biology but repeats the procedure of the ancient world, when, with additional sources of knowledge and wealth of research, it proceeds to discuss anew the great question of the origin and nature of life. Each year brings its own quota of detail and argument concerning this important and fundamental matter of modern life-science, and in more than one aspect it may be said to be the pivot around which the research of to-day turns. The subject of the origin of species, itself a burning question of biology, leads directly backwards to the origin of those powers and properties in virtue of which the species retains its hold on the world, and which lie at the root and foundation of the universe of animals and plants. Investigate the development of a living being, and you are led directly backwards to the germ from which it springs, and to the consideration of the power in virtue of which the shapeless evolves the formed, and the general grows to become the special. Study the differences and distinctions or the likenesses and resemblances that biology brings to view between animals and plants, and you will inevitably touch upon the subject of the nature of the common life which invests both regions of living beings, and which even in its most varied aspects appears to present features of strange and confusing identity between the animal kingdom on the one hand, and the plant creation on the other. Pass to consider "the records of the rocks" themselves, and in due course the question of the first beginnings of life on our planet—the when, whence, and whither of vitality—will crop up like some unperceived, but felt, presence, which hovers around the biological arcanum. The subject of life and its nature thus awaits us at the beginning of existence, as it faces us at its close. We cannot therefore feel surprise that of all questions of philosophy the nature of life should be deemed the most important, and that those who sit in high places in temples biological should so often dwell upon its varied aspects as a fit and proper theme for philosophic consideration by both gentle and simple, learned and unlearned, in scientific ways.

The investigation of life from any point of view leads us to seek in the lower confines of the living worlds, the subjects which are most likely to present us with the simplest and most elementary manifestations of living force. The life-history of the higher animal and plant appears before us as the acme of intricate operations, and as a complex collection of manufactories and organisations, the working of which may well puzzle and perplex us even in its plainest details. The mere study of a single function in the higher organism is beset with difficulties of greater or less kind. The circulation of the blood, the elaboration of sap—not to speak of the problems involved in considering animal and plant sensibility and the functions of nerves—are illustrations of points in the history of the high animal or plant which involve problems of well-nigh inexplicable nature in their study. Hence the prevailing tendency in research of the kind before us has been indicated by the selection of the lowest fields of life as the ground best adapted to yield promising results to the scientific inquirer. The lower animal or plant, as we shall presently see, makes its appearance before us as a body apparently of extremely simple structure and nature. Presenting us at the most with the appearance of a single "cell" (Fig. 19), the lower organism might be thought to yield to scientific scrutiny some clear knowledge of the nature of the powers which rule its destinies. And such a supposition might likewise be presumed to gather strength in the hopefulness of the idea that, as the higher animal or plant is but an aggregation of units, each representing the single "cell" of lower life, the study of the low organism should reveal to us, as by deputy, the secrets of the higher organisation. But the problem is hardly resolvable into conditions such as have just been indicated. The living being in higher life is not a mere collection of units, the disposition of which can be mathematically calculated and mechanically analysed. The conditions which might well enough bound the discovery of the mechanical contrivances of mankind, are not those which environ the puzzle of life. The problem which faces us as we gaze at the complex organism with its multifarious functions, is just as recondite as when, by aid of the microscope, we can look through and through the speck of protoplasm which seems hardly to warrant the term "animalcule" bestowed upon it. Thus the mere environments of the problem of living and being, constitute a difficulty of no ordinary kind, and hedge the nature of the life which is in the animal or plant with a mystery that appears to loom darkly enough, even before the shining lights of these latter days.

Although the solution of the problem concerning the nature of life may be said in some respects, therefore, to have gained but little aid from researches into the lower worlds of life that people the stagnant drop—beings which find a home in dimensions that would hardly have contained even the convenient Angels of the Schoolmen, whose ability to accommodate themselves within the limits of the minute is matter of common knowledge—still the extension of biological knowledge concerning lower organisms has been fraught with importance in certain easily discernible ways. If we have not been enabled to shout out "Eureka" to the waiting races of to-day, we have nevertheless gained some useful ideas regarding the true directions in which our difficulties must be attacked. Through the comprehension of what the lowest animals and plants are, we have been led to form certain reasonable ideas concerning what life may be. The knowledge of the conditions required to perpetuate the normal existence of living beings, has led us to recognise, in some measure, the true nature and extent of the problem that awaits the fuller knowledge of coming years for its solution. Let us, therefore, in the first place, endeavour briefly to gain some adequate ideas concerning the conditions or environments demanded for the exhibition of life in its lowest grades; since, haply, we may find in such a study a clue which may lead us towards the understanding, in theory at least, of the nature of the forces which make and control the living organism. One of the first decided steps towards the simplification of a theory of life was taken when the living contents of vegetable cells were discovered to present a striking similarity to the substance representing the essentially living part of the cells of animals. Mulder thus recognised the vegetable *protoplasm*, as he termed the soft, gelatinous matter of the vegetable cell; and Remak in turn described the animal "protoplasm." Needless to remark that this substance, described as locked up within the cells or units composing the tissues of the higher organism—animal or plant—and as constituting the active or vital parts of every living being, was identical with the matter, closely resembling white of egg in appearance, which Dujardin had named "sarcode," and of which the bodies of the lowest animals are entirely composed. Max Schultze had indeed shown that the protoplasm of animals was chemically and microscopically indistinguishable from that of plants; and that beneath the variations of form, and the diversities of life, there thus remained a curious uniformity of substance in living organisms. The life and growth of the animal was seen to depend on a substance which was apparently identical with that constituting the living basis of the plant. A curious community of substance was thus proved to underlie wide and apparently irreconcilable differences of life and habit; and out of this primary fact grew new and bolder conceptions of the nature of life than had before been ventilated by biologists at large.

To appreciate clearly and fully what is implied by the statement that the substance now widely known as "protoplasm" is a *sine quâ* *non* for the manifestation of life and vital action, let us examine a few of the aspects in which this substance makes its appearance as the medium for the exhibition of living actions. It is by no means unusual to find that familiarity with a name in the abstract implies a total inability to appreciate the concrete aspects of the substance which the name describes. Despite the wide acceptation of the name "protoplasm," it is matter of common observation that the nature of the substance itself, as well as its qualities and traits, are frequently unknown by those to whom the term is as a "household word." As a preliminary study, then, the discussion of protoplasm itself, and its varied phases, will not be without its value in the determination of its importance as "the physical basis of life." What protoplasm is, chemically and physically, may be very briefly and readily described. Chemically, it stands as the type of a class of compounds to which Mulder gave the name of "proteine" substances. Of such substances, common albumen seen in white of egg is a familiar example; and white of egg, indeed, hardly differs, save in minute chemical particulars, from protoplasm itself. The latter substance is resolvable by chemical analysis into the elements carbon, hydrogen, oxygen, and nitrogen, along with mere traces of sulphur and phosphorus. Physically, protoplasm presents itself as a clear, viscid, and semi-fluid substance, often highly granular from the presence within its substance of fatty or other particles. By immersion in a carmine solution, dead protoplasm may be stained deeply, whilst living protoplasm resists all such contact with colour; and when we have added that protoplasm can be made to contract under electrical stimulus, and that it coagulates at from 40° to 50° Cent., we shall have completed our examination of its readily observed properties.

Let us now turn to consider some of its living aspects and characters. The low-life deeps which it is the province of the microscope to explore, present us with a suitable starting-point for our inquiries; and the stagnant pool, or decomposing infusion, may be made to render from their unsavoury depths the means for scientific sweetness and light. Wandering, in its own erratic fashion, ever in search of fields and pastures new, stumbling over the fragments of weed that lie in its miniature path, and presenting us with a substance which may be paradoxically described as exhibiting every con-

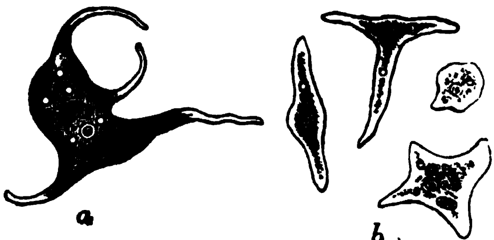


FIG. 20.—AMŒBA.

ceivable form, or as possessing no definite shape at all, we see the animalcule known as the *Amœba* (Fig. 20)—a form which has had the honourable distinction of providing a most typical illustration of lower life for all stages of biological teaching and instruction. The name *Amœba* signifies change. Of old, the being in question, drawn from the stagnant drop, and placed under the object-glass of our microscope, was named the "Proteus animalcule;" and its more modern cognomen testifies to the same characteristics of alteration and change described by the Protean simile of former days. A mere microscopic speck is the being before us, its size being measurable only in the hundredths of an inch. It will require some diligent looking ere its transparent body be clearly discerned. For it seems now and then to merge into the water amid which it lives and moves, and appears frequently to fade away into physical nothingness, just as in the sense of its vitality it may be said to hover on the verge of existence itself. When the eye lights upon the Amœba, and becomes accustomed to the dim outlines it exhibits, we are enabled likewise to note the prevailing characteristic of the animalcule in the continual tendency to well-marked physical change and contraction which its body exhibits. At no one period can it be described as exactly resembling its look or appearance at any previous stage of existence. Each moment brings new changes of shape (Fig. 20, *b*) and transmutations of outline. Now it has launched forth its soft body in one direction until it appears in a long-drawn-out line; now it has drawn this same body forwards, and has protruded its soft substance on each side into so many processes, that it resembles some solitary island with capes, headlands, and promontories jutting out in a sea of its own.

We note an animalcule, of, it may be, higher organisation than itself, to approach the Amœba. There is a momentary contact of the foreign body with the soft protoplasm of the Amœba, and instantly the latter extends its frame outwards so as to encompass the living particle, which is shortly engulfed within the contractile mass. Protoplasm is thus seen to live on protoplasm—a procedure which, by the way, in higher animal life is exactly repeated and imitated in its essential details. By this process of surrounding and enclosing its food-particles within its body, our Amœba obtains its nutriment; and one may well imagine the horror which the appearance of this gelatinous monster, engulfing, like some formless octopus, all that came in its way, would excite in lower life, were the processes of thought and thinking extant among the animalcular worlds. Thus, also, we see how the Amœba, like so many of its near neighbours, nourishes itself in the absence of a mouth and digestive system; feels, whilst it wants even the first beginnings of nerves; and moves, despite the fact that no organs of motion are developed. Watch the food-particle that has just been enclosed within the soft frame, and in due time you may perceive a little space to surround it, as if the particle were being separated from the surrounding protoplasm. Soon, the particle, if digestible at all, will disappear through the solution of its substance; and you will see it no more, save for the little space that remains awhile to mark the place where the work of digestion was carried on. Thus the process of nutrition is subserved by any part of the interior of the animalcule's frame, just as, through any part of the body, the food, in the absence of a mouth, may be ingested and received.

Nor is it less important to note how the simple acts of sensation in the Amœba are performed similarly by means which appear all inadequate for their performance. That which distinguishes the animalcule most conclusively from the great majority of its plant-neighbours, is this power of receiving sensations and of acting upon them. But for this power, the animalcule would be essentially in the position of an inorganic or lifeless mass. A solid particle floating about in the miniature sea which contains the Amœba and its neighbours, impinges upon the soft protoplasm of its body. Upon such a stimulus, the protoplasm, as we have seen, contracts, and the food-particle is duly surrounded and engulfed by the living mass of the animalcule. It may truly be affirmed that the first nervous acts are strictly utilitarian in their nature. Their use and purport is that of enabling the animalcule to obtain its food. Sensation is thus unquestionably present in this low form of animal life. Indeed, there are few, if any, naturalists who would not assent to the statement that an Amœba, lowly organised as it is, is more highly sensitive than a tapeworm possessing an organisation of some complexity—or a Sacculina, which attaches itself to the bodies of crabs, and whose only sign of life consists in the slow pulsations of its bag-like body.

But this power of receiving sensations is not the only likeness which the Amœba, in respect of its innervation, exhibits to higher animal life. Its protoplasm not only receives sensations; it is also able to act upon information received. The mere contact of the food-particle with the protoplasmic body, is but the prelude to the active contractions of its mass, which are directed towards the seizure of nutriment. And thus we become aware of the fact that not only is this power of "contractility," or of acting upon sensations received, the distinctive property of protoplasm, but that in such a power the actions of higher life are closely imitated. The nervous phenomena which, when occurring in higher existence, are collectively named "reflex action," are essentially of a kind similar to those acts which we see taking place in a body composed of a speck of protoplasm. There is the closest parallelism between our acts of withdrawing our head from a blow, or of closing our eyelids from the same cause, and the action of the animalcule in ingesting its food. Both higher and lower organisms "experience" a sensation, and are capable of acting upon it. The real difference exists in the complexity of the mechanism which responds, and not in the manner in which the stimulus is received or the corresponding act performed.

Summing up the facts which a study of the Amœba has elicited, we learn, firstly, that a minute speck of the sensitive living matter we term "protoplasm" may of itself constitute a living being, capable perfectly of maintaining its existence and its relations with the external world, and presenting in its life-history many striking analogies with life in its higher and more complicated developments. We next see simplicity of structure united to a complex physiology or way of life; and we learn that, even in its simplest and most primitive condition, this "protoplasm" of ours may present us, in the endeavour to explain its actions and behaviour, with problems whose solution is practically the despair of many minds amongst us. If it puzzles such minds to see the connection between the molecular stirrage of the human brain-cells and consciousness, the question, "How does a sensation received by the soft protoplasm of an Amœba become converted into contraction of that body?" must be regarded as equally unanswerable. Nay, we may go further, and affirm that the difficulty of reply arises primarily because of the identity of the two problems. As we shall presently see, both questions involve like considerations; both deal with states of protoplasm; both consider the problem of protoplasmic molecules and their movements as related to actions and motions, which exhibit in higher life the addendum termed "consciousness"—although whether the latter term may not, after all, be simply a name implying another phase of protoplasmic motion is a suggestion worth our consideration. Suffice it to say, however, that, as yet, there is as much mystery involved in the explanation of the movements of an Amœba as in the molecular play of the brain-cells of a man. And although the admission may furnish considerations which inveigh against the theory of the evolution of the higher mind from the lower sensations, the argument is two-edged after all. If so much that is inexplicable, and apparently complex, exists within the narrow compass of the animalcule's irritability, it may be reasonably said that, of all things, it were most foolish to deny the possibility of these as yet unknown beginnings of nerve-force having been the forerunners of brain and mind. Eliminate these beginnings from view, indeed, and you will find it hard on any save a theory of special and independent creation, to account for the origin of the mental powers which successively mark the higher animal and the man.

We have, however, been studying but one phase of protoplasmic existence, and as such, our knowledge can afford us but little aid towards the consideration of the wider part which this substance plays in the phenomena of both animal and vegetable existence.

Selecting the field of plant-life for our next essay on the powers and nature of protoplasm, we find in this particular region abundant proof that the peculiarities of protoplasm are in no wise affected by its forming part of the plant-*régime*. Suppose we study under the microscope the nature of the protoplasm which is locked up within the "cells" of such plant-organisms as Chara, Tradescantia (Fig. 21), and Vallisneria, or within the cells comprising the stinging hair of the nettle's leaf. We may readily see that active and incessant motion is the attribute of the imprisoned living matter of the plant-cells. Ceaseless currents of particles agitate the plant-protoplasm, which, but for the insidious operation of "osmosis," whereby fluids pass in and out of the cells, would seem to be literally shut out from all participation in outward or external affairs. The cell of the leaf-hair of Tradescantia (Fig. 21), for instance, exhibits an incessant flow of protoplasmic granules hurrying steadily in definite directions, like the ordered traffic in the streets of a great city. Stream of protoplasmic currents unites with stream, and ceaseless mutation of the contents of the cell is the result. In the nettle-hair the same phenomenon meets the gaze of the microscopist. Here we find the same protoplasmic substance lining the woody matter that forms the external wall of the cell. Constantly does this living lining alter and change its shape with wave-like contractions of its substance, and the granules which exist in the fluid contents of the cell, hurry in various directions with the same activity that we remarked in the cell of Tradescantia. We thus awaken to the fact that in the seemingly inert and unconscious field of plant-life there is activity enough, if we may but fortify our seeing powers with the microscope, and peer awhile into the inner recesses, and into the nooks and crannies of the vegetable world.

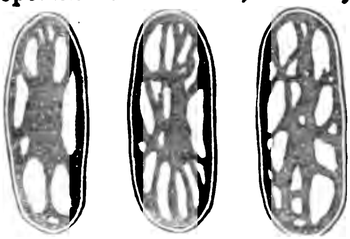


FIG. 21.—Cell of a plant, (*Tradescantia*), drawn at intervals, and showing changes in the contained protoplasm.

Nor may we neglect to note in passing that, upon some higher development of this same protoplasmic sensitiveness and activity than is usual and common in vegetables, the marked powers of sensation of such plants as the Venus's fly-trap and the Sensitive Plants must depend. Locked up within the hard cell-wall, which, as a rule, it is the business of plant-growth as distinguished from animal increase to develop, there is little wonder that we have come to regard the plant as an organism which feels not, and which is apparently as destitute of all sensation as the world of inorganic things. But the deeper view of plant-existence shows us the fallacy of the common notion regarding the non-sensitiveness of plants. Their protoplasm is as highly contractile under stimulus as is that of the animal. Conceive of a vegetable cell being ruptured—as, indeed, takes place in certain phases of lower plant-life—and we should find escaping therefrom protoplasm as active as that of our Amœba, and which, indeed, would comport itself in an exactly similar fashion to that animalcule. Consider, for instance, what takes place in the multiplication of the lower plant-life that forms "the green mantle of the stagnant pool." Here, in due season, the protoplasm, found in the interior of the cells of which these green *Confervæ* of the stagnant pool are composed, will break up into minute particles, which are duly discharged from custody by the rupture of the cell-wall that formerly imprisoned them. These minute bodies, thus liberated, are named "zoospores." They flit about in the water, and exhibit as free and active an existence as the animalcules which disport themselves side by side with these plant-germs; and they likewise exhibit an identity of protoplasmic composition with the lower animals that people the stagnant depths. After a period spent in this active existence, the zoospores settle down and grow each into a new plant resembling that from which it sprang. Or, mayhap, meeting with a fellow-spore, a more intricate relationship may be induced; a third and new body may be produced as the result of this contact; and from this new body—foreshadowing the "seed" of the higher plant—the adult Conferva will in due time grow. Thus we find that, in addition to the resemblance between the protoplasm of the animal and that of the plant in respect of appearance and composition, there exists a closer likeness still in the common movements which protoplasm, whether derived from the animal or the vegetable, exhibits.

It is not necessary that we should dwell upon other examples of the marked irritability of protoplasm in lower plant-life to demonstrate the community of phenomena which this substance is everywhere seen to exhibit in its simple and primitive condition. The life-history of the commonest seaweed that fringes the rocks, would show phenomena of similar kind, and would convince us that power of motion, by common consent the exclusive right and property of the animal, is rather to be viewed as a quality of the protoplasm which forms the living parts of both series of organisms. For, like many of its lower neighbours, the seaweed begins its existence as a minute speck of protoplasm that possesses from nature a roving commission, and swims about freely in its native waters by means of *cilia*, or filaments, resembling those by which the animalcules propel themselves. Ultimately this roving life is abandoned for the stay-at-home existence of the mature seaweed, which in due course arises by cell-growth and protoplasmic multiplication from the once active "spore." Whether studied in the lower animal or in the plant, protoplasm is thus seen to possess essentially the same qualities and properties which everywhere and primarily distinguish it as living matter. It remains to be seen whether the examination of higher animal life will destroy the analogies and similarities which are so plainly apparent in the lower confines of the kingdom of living nature.

In its complex entirety, the body of a man appears to present us with no features of structural kind which can serve in the least degree to approximate the higher type to lower forms and types of life. Organ and parts in systems and series more or less complicated, constitute the framework of the body, whose physiology or functional activity is in turn of a correspondingly intricate character. The simplest tissue of man's frame would, at first sight, appear to present a complexity defying reconciliation with any simpler phase of structure or life. What seems true of the human type may be held to be equally correct when applied to the case of much lower animals, which appear to be far enough removed in their own way from the primitive simplicity of the protoplasmic Amœba and its allies. A snail or a worm, at first sight, appears, in fact, to be as distant from the protoplasmic and primitive stage of organisation as man himself, in that each is built up of organs exhibiting a complicated structure and highly specialised arrangement of parts. In such a case, what are the likenesses or differences between the higher and lower organisms which the scientific examination of the complex frame reveals? Let anatomy and physiology together furnish the reply.

The microscopic anatomy of the tissues of which man's body consists, reveals to us a fundamental unity of organisation, which is both striking and important in all its particulars and aspects. Every primer of physiology teaches us the lesson that man's body, like the

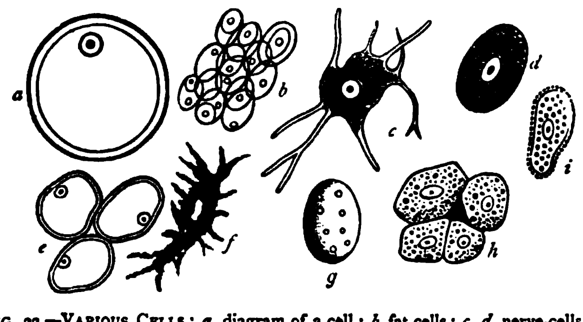


FIG. 22.—VARIOUS CELLS: *a*, diagram of a cell; *b*, fat cells; *c*, *d*, nerve-cells; *e*, cartilage-cells; *f*, pigment-cell; *g*, a plant-cell; *h*, liver-cells; *i*, cartilage-cell.

frames of all other animals above the rank of the Amœba and its nearest kith and kin, consists of definite layers of minute "cells" (Fig. 22), grouped together to form the definite "tissues" of the body. When we speak of the skin, for instance, we are merely indicating a layer of microscopic cells. When we speak of brain tissue we are again discoursing of cells (Fig. 22, *c*, *d*); and bone itself, in its essential and living parts, is a true cellular tissue. In the human body, it is true, there are muscular fibres, nerve fibres, tendon fibres, and other structures of like nature; but the physiologist points out that the presence of these latter elements does not invalidate his previous statement concerning the universal cellular composition of the frame. For the body at first consists entirely of cells, and most of the fibres of the body—as, for example, the fibres of muscle by means of which we move, or those of the crystalline lens of the eye—can be shown to be formed directly from cells by the elongation or modification of the latter; whilst the growth and renewal of all fibres take place through the production of new cell-elements. It may be assumed as an axiom of physiology that the bodies of all animals, man included, are formed of cells, which become differentiated to form cellular tissues in the one case, or still further modified to form fibres in the other.

Such information, all-important as it undoubtedly is, leaves us, however, on the mere confines of our physiological and anatomical study of the higher frame. To understand clearly the relations of the primitive protoplasmic animalcule with the "lord of creation" himself, it is needful to pay a little attention to some further details of microscopical study. Suppose that we examine under the microscope a transverse section of bone. In such research we shall assuredly light upon some facts of interest as assisting our comprehension of the true typical structure of the most complicated organism in nature. A cross section of bone shows us that the apparently solid tissue is everywhere perforated by the minute "canals" to which Clopton Havers gave his name, and which contain and protect the blood-vessels that nourish the bone. Each Haversian canal of bone is seen to be surrounded by concentric circles of bony matter. When these circles are minutely examined, each is found to consist of elongated spaces, called "lacunæ," placed at irregular intervals, and which communicate with each other by minute processes called "canaliculi." Imagine a central lake to be surrounded by circles of smaller lakes, the latter communicating with each other by a complex series of branching rivers, and a fair idea will be gained respecting the arrangement of the minute elements of a bone. In a living bone the disposition of parts is not altered from that disclosed in its microscopic section. The blood-vessels ministering to the nutrition of the bone traverse the Haversian canals already mentioned. Each "lacuna" or lake, however, is occupied by a minute mass of protoplasm, which in all essential respects might be compared to an Amœba; and the protoplasm of one lacuna sends out minute processes of its substance along the communicating channels already alluded to, and thus communicates with the living matter of the neighbouring spaces. So that, could we obtain a perfect view of the living protoplasm of a bone, we should find that, when removed from the lacunæ, these living parts would appear before us somewhat like a spider's web, and as a connected series of Amœba-like masses of protoplasm, adhering together by the minute processes just described, and roughly reproducing for us the form and outline of the bone. These masses of protoplasm are the "cells" of the bone on which depend the life, nourishment, and general welfare of that structure. We thus learn the curious fact that the most solid and enduring tissue of our body, in its essential nature, represents a collection of Amœba-like masses of protoplasm absolutely undistinguishable, be it also remarked, in nature from the similar matter which moves and gropes in the gutters of our housetops or in the stagnant pools. As the plant-cell imprisons its protoplasm within a thick cell-wall, so our bone-cells in like manner form our skeleton by their special manner of growth and development. And it requires no great depth of thought to perceive the similarity of the elements of the human tissue to those which constitute the essentials of lower life at large.

Not less striking are the revelations which research into the fundamental structure of the nervous system displays. Nerve-cells (Fig. 22, *c*, *d*) and nerve-fibres together comprise the body's telegraph system; the fibres of nerves being primitively formed like other fibres of the body from cells. The nerve-cell has come to be fully recognised as that part of the nervous mechanism which produces and evolves nerve-force—that subtlest of life's forces, now seen to be represented in the movement of a limb, and now in the impassioned utterances of mind. The nerve-fibre simply carries and distributes the nerve-force generated by the cells, but possesses on its own account no power of evolving the characteristic force that in varied fashions rules the wide universe of human life and of lower existence as well. When the structure of the brain and spinal cord, as the two chief nerve-centres of the body, is examined, both cells and fibres are found to enter into their composition; but the cells alone exist in those parts—such as the grey or external layer of the brain—in which nerve-force is evolved. Nerve-cells vary in size and shape. They may be simple (Fig. 22, *d*) or complex (*c*) in form, and range from the round or spherical to the branched and irregular in form. Some of the "multipolar" (*c*) nerve-cells—as those possessing a plurality of processes are named—might well enough suggest to the imaginative mind a resemblance to Amœba in shape, as they of a certainty are related to that animalcule in the protoplasmic nature of their contents and structure. For the essential element in the nerve-cell is protoplasm, pure and simple; undistinguishable in its chemistry and histology from the substance which we discern in the animalcule or in the bone-cell. Whatever mental powers are exhibited by man, or by animals which possess a brain or nerve-centres of any kind, are the direct products of the nerve-energy stowed up within the cells of the nerve-centres; and, as we have seen, protoplasm constitutes the essential *materies* of these cells. That differences of function, wide and apparent, exist between the protoplasm of the bone-cell and that of the nerve-cell need not be even alluded to as a fact of primary significance when considering the physiology of these varied organs. But sufficient for our present purpose is the still broader fact which demonstrates the community of protoplasm as the one living essential of the human frame, whether concerned in the work of forming bone, secreting bile, producing movement, or evolving thought. Thus it remains a stable fact of human existence that on the special qualities and properties of the protoplasm or living contents of cells, depend all the actions and the total activity and individuality of our lives. It is by means of protoplasm that the cells of the liver secrete bile; it is through the properties of protoplasm producing new cells that a scratch heals, or other breach of bodily continuity is repaired; and it is by means of a peculiar functional development of this same substance that we are enabled "to lay the flattering unction to our souls" that we are the possessors of mind, intelligence, and will.

It might also be shown, as one of the most curious facts of physiology, that we harbour in our arteries and veins thousands of protoplasmic specks which, when viewed under the microscope, behave as do veritable Amœbæ. Such are the "white corpuscles" of the blood, which may be seen to undergo mutations of form strictly comparable to the changes of shape that give to the Amœba its characteristic aspect, and which alterations, from this resemblance, have been named "amœboid" by the physiologist. Enough has already been said of the structural composition of the human body to show that it derives its living activity from the protoplasm which is everywhere scattered throughout its tissues, and which represents the typical living centre of each cell or tissue in which it occurs. But the case for the universality of protoplasm, as the true and only medium by which life is exhibited, increases in importance when the early outlines and forecasts of development are even briefly chronicled. The nearer we approach the primitive condition of living organisms, the more apparent does the similarity between the earliest stages of all organisms become. An Amœba gives origin to new animalcules by simply dividing its body in two, when each half swims away as an independent being, to begin life on its own account. Here, there is an absolute and necessary identity of substance between the producer and the produced. But even in higher grades of life, where the process of development is by no means so simply carried out as in Amœba, there is a wonderful similarity between the individual germs of higher animals, as well as between such germs and the adult and permanent stages of animalcular life. No anatomist could venture, for instance, to express an opinion as to the identity of the germs of the highest class of animals. A protoplasmic germ, presenting essentially the same structure and appearance as that of the dog and sheep, gives origin to man himself; and the stages of development which evolve the one are strictly comparable in all save the very latest to those that produce the other. Thus man arises from a germ of protoplasm measuring about the one-hundred-and-twentieth part of an inch in diameter, the material substance of which cannot be distinguished by any microscopic or chemical tests from that which is destined to give origin to his canine friend, or from that of which the shapeless frame of the Amœba is composed. Indeed, the eggs and germs of many animals are strictly Amœba-like in their nature and motions. The germ of a sponge creeps about within the parent organism in a fashion undistinguishable from the familiar animalcule; and there are zoophytes and other animals whose eggs exhibit the same exact Amœba-like appearance which man's own white blood-corpuscles evince. It is thus a plain fact that whatever complexities of body or of mind we find exhibited in the animal world, arise from like matter and similar substance. That man, equally with the monad and the Conferva, owes his origin to a protoplasmic germ, in which are contained all the potentialities and possibilities of his after-development, is no piece of scientific romance, but demonstrable truth. Protoplasm begins our life, as it continues that existence for us; and in this respect the Amœba may be regarded as the type of all living things, or, like the famous freebooter of the ballad, as veritable "lord of all" that lives.

The universality of protoplasm as the basis of life may be held as fully proved. Apart from the presence of this substance, life is unknown to exist. It is seen constituting the essential living parts of animals and plants, from lowest to highest. Whale and animalcule, triton and minnow, the giant pine and the lichen, each and all owe to protoplasm their primary vitality and the powers which mark their varied lives. As Dr. Allman puts it, in an address to the British Association, "we are thus led to the conception of an essential unity in the two great kingdoms of organic nature—a structural unity in the fact that every living being has protoplasm as the essential matter of every living element of its structure, and a physiological unity in the universal attribute of irritability which has its seat in this same protoplasm, and is the prime mover in every phenomenon of life. We have seen," continues Dr. Allman, "how little mere form has to do with the essential properties of protoplasm. This [illegible] shape itself into cells, and the cells may combine into organs in ever-increasing complexity, and protoplasm-force may thus be intensified, and, by the mechanism of organisation, turned to the best possible account; but we must still go back to protoplasm as a naked, formless plasma, if we would find, freed from all non-essential complications, the agent to which has been assigned the duty of building up structure, and of transforming the energy of lifeless matter into that of living."

How much nearer to the great question of the origin and nature of life do such considerations lead us? is a justifiable query which faces us at the close of these inquiries, as it formed the key-note with which we began our brief study of the mystery of living and being. It cannot be doubted that the research of recent years has at least brought us nearer to our real difficulties than before. It counts for something in a subject like the present that even the boundaries of our knowledge and the environments of our ignorance should be clearly perceived; and this much, at least, the inquiries concerning protoplasm have accomplished. We now know that at last we are face to face with the final stage in the question before us—that the puzzles of protoplasm collectively constitute the one mystery of life. To such a decision, every fact of recent research seems to lead. The knowledge that there is not one life of the animal and another existence of the plant, but that both lives are really similar in their essential manifestations, is one fact which leads us directly to regard protoplasm and its constitution as the repositories of the secret of life's nature. One consideration which merits special remark in connection with the subject of protoplasm and its relations to life exists in the apparent truism that all forms of protoplasm, however alike in appearance and composition science may and does declare them to be, are not identical in their potentialities. They do not, in other words, all possess similar powers of becoming similar organisms. The speck which remains an Amœba, has no power of evolving from its substance a higher form of life. The protoplasmic spore of a seaweed is a seaweed still, despite its similarity to other or higher forms of plant-germs. The germ of the sponge, again, remains possessed of the powers which can convert it into a sponge alone. And the differences between such protoplasmic specks and the germ which is destined to evolve the human frame can only be declared as of immense extent, and as equalling in their nature the wide structural and functional distinctions we draw betwixt the sponge and the man. Of such differences in the inherent nature of protoplasm under different conditions we are as yet in complete ignorance. Their elucidation is really the explanation of heredity or the law of likeness. The mystery why family face and features, along with even habits and gestures, should be rigidly and perfectly transmitted from parent to offspring, really includes the puzzle which besets the real differences between one speck of protoplasm and another and apparently similar speck.

But our want of knowledge of such points may not leave untouched the primary question concerning the nature of life, to which all the properties and qualities of protoplasm, all the varied forms and faces of living beings, are due. On the contrary, it is possible by analogy to arrive at some broad views concerning the nature of life at large, and to such considerations we may now shortly attend. Physiology points out to us that the properties of protoplasm and all its powers of being and becoming are resident within its own substance, and are dependent upon the energy of which it is the seat. Supply appropriate conditions, and the forces of the protoplasm will convert the primitive germ into the form of its progenitor. There is a transformation of force and matter of one kind, into force and matter of another kind therein involved. Such facts point to material powers and forces resident in, and peculiar to, protoplasm as the prime movers of the changes and developments that substance undergoes. As clearly, too, does the transmission of parental likeness from generation to generation argue for the existence of some material and physical basis for the carriage, by the protoplasm-germ, of the features of the species. If so much be admitted, it seems illogical to deny that whatever properties the protoplasm of germ or adult exhibits depend, strictly speaking, upon the chemical and physical properties of that substance. Thus we approach the idea that this mysterious "life," which no one has yet successfully defined—for the plain reason that the terms of the definition are unknown—simply represents the sum-total of the energies of the physical, chemical, and other properties of protoplasm. Nowhere do we find life dissociated from protoplasm; and this fact alone argues in favour of the view that the "vital force" of the scientist or the "vital spark" of the poet, is in each case merely the convenient and summary expression of that high form of energy, which corresponds to no one force in nature, but to all combined.

If this hypothesis be deemed essentially materialistic—as unquestionably it will be from certain points of view—its supporters still possess a distinct coign of vantage in a simple and logical appeal to the facts and phenomena of nature and life as they stand. In addition to the pregnant fact just mentioned, namely, that life requires for its exhibition a material basis seen in protoplasm, the mere considerations that this substance is composed of no unknown elements, but of well-defined and common substances, and that its composition is not ethereal but material, support the view that life is no mysterious *aura*, but a collocation of the forces and energies and of the material substances which make protoplasm. Life is a property of protoplasm—such is the latest product of scientific thought and research. The forces which make protoplasm are regarded as those which make life; and although the exact relationship of these forces is as yet unknown, analogy leads us to believe that they are not materially different, if they are different at all, from those which have made the world of inorganic matter what it is. It is analogy, too, which reminds us that certain forces produce, under combination, very different results from those which they exert when acting in separate array. The relationship and correlation of the physical forces not merely teems with examples of such results, but leads us to think of the possibility and probability that life remains a mystery to us simply because the terms under which its component forces are combined are as yet unknown. In any case, we require to postulate a "life-force" of one kind or another. It remains for us to choose between the "vital force" of former decades of biology—a term committing itself to no explanation of vital phenomena whatever—and the idea that in the properties of protoplasm—derived whence and how we, as yet, know not—we find the true nature of life.

But analogy rests not here. An extension of thoughts like the foregoing leads us towards the world of inorganic matter with the view of inquiring whether there exist any links or connections between that lifeless universe and the living world which claims protoplasm as its universal substratum. The forces which act upon the lifeless world are those which also affect animals and plants; but the latter are enabled to resist, alter, and modify the action of these forces in greater or less degree, whilst lifeless matter exists and is acted upon without response. Otherwise, however, the phenomena of the inorganic world, despite their sharp demarcation from the phases of life, may be regarded as presenting us with many facts of origin as inexplicable as those exhibited by living beings. It has well been remarked that the growth of the crystal, taking place in virtue of physical laws, to attain an exact and unvarying form, is as mysterious as the growth of the tree; and that common salt should crystallise in the form of the cube is as profound a mystery as that an acorn should become an oak, or another protoplasmic germ evolve the human form. If we are to assume that the forces which rule the world of life are inexplicable simply because they are living forces, it might equally well be maintained that the inorganic world and its ways should be the subjects of similar mysticism. Far more rational, because more likely to be true, are the ideas which lead us to note in the living world the highest term to which matter may attain. As the living world is dependent on the non-living for its support, as we are both in the earth and of the earth, so may we conceive that the forces which mould the world, which disperse the waters and rule the clouds, have contributed in their highest manifestations to combine matter into its most subtle combinations in the form of the animal and in the guise of the plant. Huxley's words are worth weighing when he says: "It must not be supposed that the differences between living and non-living matter are such as to bear out the assumption that the forces at work in the one are different from those which are to be met with in the other. Considered apart from the phenomena of consciousness, the phenomena of life are all dependent upon the working of the same physical and chemical forces as those which are active in the rest of the world. It may be convenient to use the terms 'vitality' and 'vital force' to denote the causes of certain great groups of natural operations, as we employ the names of 'electricity' and 'electrical force' to denote others; but it ceases to be proper to do so if such a name implies the absurd assumption that either 'electricity' or 'vitality' is an entity playing the part of an efficient cause of electrical or vital phenomena. A mass of living protoplasm is simply a molecular machine of great complexity, the total results of the working of which, or its vital phenomena, depend, on the one hand, upon its construction, and on the other upon the energy supplied to it; and to speak of 'vitality' as anything but the name of a series of operations, is as if one should talk of the 'horology' of a clock."

Although research has not placed the puzzle of life and its solution at our feet, our inquiries have at least served to indicate the direction towards which modern scientific faith is slowly but surely tending. The search after a material cause for phenomena, formerly regarded as thoroughly occult or supernatural in origin, is not a feature limited to life-science alone. Such a characteristic of modern research indicates with sufficient clearness the fact that, as biology and physics become more intimately connected, the explanations of the phenomena of life will rest more and more firmly upon a purely physical and appreciable basis. That life has had a distinct beginning upon this earth's surface is proved by astronomical and geological deductions. That life appeared on this world's surface not in its present fulness, but in an order leading from simple forms to those of an ever-increasing complexity, is an inference which geology proves, and which the study of animal and plant development fully supports. That the first traces of life existed in the form of protoplasmic germs, represented to-day by the lowest of animal and plant forms—or rather by those organisms occupying the debatable territory between the animal and plant worlds—is well-nigh as warrantable a supposition as any of the preceding. And last of all, that these first traces of protoplasm were formed by the intercalation of new combinations of the matter and force already and previously existing in the universe, is no mere unsupported speculation, but one to which chemistry and physics lend a willing countenance. Living beings depend on the outer world for the means of subsistence to-day. Is it more wonderful or less logical to conceive that, at the beginning, the living worlds derived their substance and their energy wholly from the same source? The affirmative answer seems to be that which science tends to supply, with the qualification that, once introduced into the universe, living matter is capable of indefinite self-reproduction, without necessitating any appeal for aid, by way of fresh "creation" of protoplasm, to the inorganic world. As Dr. Allman has remarked, it is certain "that every living creature, from the simplest dweller on the confines of organisation up to the mightiest and most complex organism, has its origin in pre-existent living matter—that the protoplasm of to-day is but the continuation of the protoplasm of other ages, handed down to us through periods of indefinable and indeterminable time." The harmony of these inferences with the doctrine of evolution is manifest. The common origin of animal and vegetable life, and the further unity of nature involved in the idea that the living worlds are in reality the outcome of the lifeless past, constitute thoughts which leave no break in the harmony of creation. "There is grandeur," to quote Mr. Darwin's words, "in this view of life," which, founded upon scientific research, simply commits its supporters to the wholesome philosophic truth, that the ways of all living beings are ordered in conformity with the great system of natural law, whose operation is seen with equal clearness in the formation of a world or the falling of a tear.

V.

THE EVIDENCE FROM RUDIMENTARY ORGANS.

In the exercise of his scientific attainments, there is one aspect in which the naturalist of to-day bears a certain likeness to the detective officer. The latter is perpetually endeavouring to "strike the trail" of the offender through his dexterity in the discovery of clues to the movements of the pursued, and attains his end most surely and speedily when the traces he has selected are of trustworthy kind. The naturalist, on his part, has frequently to follow the history of an animal or plant, or it may be that of a single organ or part in either, through a literal maze of difficulties and possibilities. His search after the relationship of an animal may be fraught with as great difficulty as that which attends the discovery of a "missing heir" or lost relative in actual life; and his success in his mission is found to depend, as does that of the detective's work, simply on the excellence and trustworthiness of the clues he possesses, and on the judicious use to which he puts his "information received." It cannot be denied, however, that modern aspects of science and present-day tendencies in research have largely increased the resemblance between the enforced duties of the criminal investigator and the self-imposed task of the biologist. When, formerly, the order of nature was regarded as being of unaltering kind and of stable constitution, naturalists regarded animals and plants simply as they existed. There was of old no looking into the questions of biology in the light of "what might have been;" because the day was not yet when change and evolution were regarded as representing the true order of the world. When, however, the idea that the universe both of living and non-living matter had an ordered past dawned upon the minds of scientists, the necessity for tracing that past was forced upon them as a bounden duty. With no written history to guide them, the scientific searchers were forced to read the "sermons in stones" which nature had delivered ages ago. Without clear and unmistaken records to point the way, they had to seek for clues and traces to nature's meaning in the structure and development of animals and plants; and, as frequently happens in commonplace history, the earnest searcher often found a helping hand where he least thought it might appear, and frequently discovered an important clue in a circumstance or object of the most unlikely kind.

Readers whose tastes are not materially scientific have doubtless heard much of "missing links" of nature, especially in connection with the gaps which exist between the human territory and ape-land. Indeed, the phrase has come to be understood as applying almost entirely and specifically to the absence of connecting forms between man and the apes—forms for which, in one sense, no necessity exists, inasmuch as Mr. Darwin's theory does not demand that the gorilla or any of his compeers should be directly connected with man. The gorilla with his nearest relation lives, so to speak, at the top of his own branch in the great tree of life, whilst man exists at the top of another higher and entirely different bough. The connection between the human and lower types is made theoretically to exist at some lower part of the stem when, from a common ancestor, the human and ape types took divergent roads and ways towards the ranks of nature's aristocracy.

But although, in some cases, the need for "missing links" is seen, even theoretically, to be non-existent, or at least of a widely different nature from that supposed by the popular mind, there are yet cases in which that need is very apparent, and wherein, through the persistent tracing of the clues nature has afforded, the past history of more than one race of animals and plants has been made plain and apparent. Of such clues—which are really mere traces, and nothing more—there are no better examples than the curious fragments of structures found in many animals and plants, and named "rudimentary organs." An animal or plant is thus found to possess a mere trace of an organ or part which, so far as the highest exercise of human judgment may decide, is of not the slightest utility to the being. It is invariable in its presence, and as fixed in its uselessness. It bears no relation to the existing life or wants of the animal, but may in some cases—as, for example, in a certain little rudimentary pocket in man's digestive system, serving as an inconvenient receptacle for plum-stones and like foreign bodies—prove a source of absolute disadvantage or even danger. On what theory can the presence of such organs and parts be accounted for? is a question of extremely natural kind. The replies at the command of intelligent humanity are but two. Either the animal was created with the useless appendage in question—a supposition which includes the idea that Nature, after all, is somewhat of a bungler, and that nothing further or more comprehensible than the fiat "it is so," can be said on the subject. Or, secondly, we may elect to explain the puzzle by the assertion that the "rudimentary organ" of the existing animal represents a part once fully developed in that animal's remote ancestors, but now

Dwindled to the shortest span.

The rudimentary organ or appendage is regarded by evolution as being represented in the animal or plant of to-day as a legitimate heritage derived from its ancestor. It is, in short, a family feature, to which the living being is the "rightful heir," but which has fallen, through the operation of natural laws and conditions, into disuse, and has accordingly suffered in the career of living nature "down the ringing grooves of change." Necessarily, this second and rational explanation of the rudimentary appendages of animals and plants is founded on the supposition that Nature and Nature's creatures are continually undergoing alterations, and that they have been modified in the past, as they will be in all time to come. The explanation thus afforded of the nature and origin of these disused parts is endorsed by the fuller knowledge of their history; whilst, from a study apparently of insignificant interest, may be shown how certain of our living neighbours, along with ourselves, have, from lower states, and from the dawning epochs of the world, literally taken their place "in the foremost files of time."

As most persons who have attentively looked at any common plant can tell, four parts are included in a perfect flower. These parts

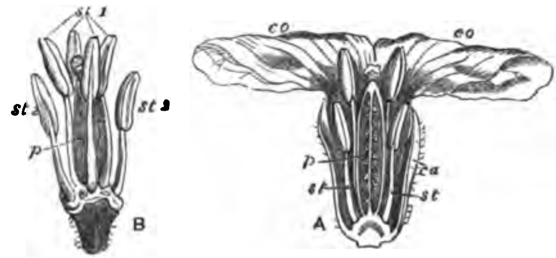


FIG. 23.—STRUCTURE OF WALLFLOWER.

or sets of organs, as seen in the wallflower, consist (Fig. 23), firstly, of an outer covering coloured green, and named the "calyx" (*ca*). Then comes the blossom or flower itself, forming the "corolla" (*co*). Inside the corolla we find certain stalked organs, each bearing a little head or "anther," filled with a yellow dust, the "pollen." These organs are the "stamens" (*st*). Lastly, in the centre of the flower we note the "pistil" (*p*), or organ devoted to the production of "ovules." The latter, when duly fertilised by being brought into contact with the "pollen" of the stamens, become "seeds," and are capable of growing up, when planted, into new plants.

Now, the botanist will inform us that it is a matter of common experience to find some individual plants of a species with well-developed petals or blossoms, and other individuals of the same species with petals in a rudimentary condition; thus proving that the production of imperfect parts in flowers occurs as an ordinary event under our own eyes, and under the common conditions of plant life. The natural order of plants to which Snapdragon belongs presents a peculiarity, inasmuch as, in most of its members one of the five stamens is abortive or rudimentary. It should be borne in mind that the botanist possesses a highly interesting and exact method of ascertaining how many parts or organs should be represented in plants. He places his reliance in this respect on the working of what may be called the "law of symmetry." The operation of this law, which may be said to be founded on wide experience, tends to produce a correspondence in numbers between the parts in the four sets of organs of which we have just noted a flower to be composed. Thus, when we count five parts in the green calyx of a plant, we expect to find five blossoms (or petals) in its corolla; five stamens (or some multiple of five), and five parts (or some multiple of that number) in the pistil. Where there appears to be a lack of this numerical correspondence, the botanist concludes that some violation of the law of symmetry has taken place, and that some parts or organs which should normally have been developed have been altered or suppressed. His reasoning, in fact, proceeds on the plain basis of first establishing, through experience, the normal number and condition of parts in the flower of any given order of plants, and of thereafter accounting by suppression or non-development for the absence of parts he expected to have been represented.

Now, in the Snapdragon tribe we find, as a general rule, five parts in the calyx, five petals in the corolla, but only four stamens. Such a condition of matters is well seen in the flower of frog's-mouth (*Antirrhinum*), where we find four stamens, two being long and two short (Fig. 24, A, s^1 s^2), as the complement of the flower. We account for the absence of a fifth stamen by saying it is abortive; and the rudiment of this missing stamen may also be found in the flower. But a natural reflection arises at this point, in the form of the query, Have we any means of ascertaining if our expectation that a fifth stamen should be developed is rational and well founded? May not the plant, in other words, have been "created so"? Fortunately for science, nature gives us a clue to the discovery of the truth in this as in many other cases. In one genus of these plants (*Scrophularia*) we find a rudiment of a fifth stamen (Fig. 24, B s); and in Snapdragon itself this fifth stamen becomes

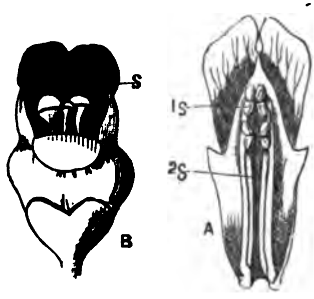


FIG. 24.—FLOWER OF FROG'S-MOUTH. A, Flower of Frog's-mouth; B, Flower of Figwort or *Scrophularia*.

occasionally fully developed; whilst another plant of the order (*Verbascum*) possesses five stamens as its constant provision. Unless, therefore, we are to maintain that nature is capricious beyond our utmost belief, we are rationally bound to believe that the rudimentary fifth stamen of *Scrophularia*, and the absent fifth stamen of other plants of its order, present us with an example of modification and suppression respectively. The now rudimentary stamen is the representative of an organ once perfect and fully developed in these flowers, and which is perpetuated by the natural law of inheritance until conditions, to be hereafter noticed, shall have caused it to entirely disappear. The case for the natural modification, and that against the imperfect creation of such flowers, is proved by an ingenious experiment of Kölreuter's, upon plants which have the stamens and pistils situated in different plants, instead of being contained in the same flower, as is ordinarily the case. Some "staminate" or stamen-possessing flowers had the merest rudiment of the pistil developed, whilst another set had a well-developed pistil. When these two species were "crossed" in their cultivation, the "hybrids" or mule progeny thus produced, evinced a marked increase in the development of the abortive organ. This experiment not only proved that, under certain conditions, the rudimentary pistil could be improved and bettered, but also confirmed the identity of the two pistils, and the high probability that the abortive organ in the one flower was simply the degraded representative of the well-developed part of the other.

As a final example of the manner in which we receive clues towards the explanation of the modifications of flowers, the case of the wallflower is somewhat interesting. This plant and its neighbours possess the parts of the flower in fours (Fig. 23, A). There are four sepals and four petals, whilst six stamens (Fig. 23, B) are developed; the pistil possessing only two parts. Here the law of symmetry would lead us to expect either four stamens or eight—the latter number being a multiple of four. The clue to this modification is found in the arrangement of the stamens. We find that four of the wallflower's stamens are long (Fig. 23, B, st^1), whilst two (st^2) are short. The four stamens form a regular inner series or circle, the two short stamens being placed, in a somewhat solitary fashion, outside the others. This condition of matters points probably to the suppression of two of an originally complete outer row of four stamens, and we receive a clue concerning the probability of this view by finding that in some other flowers of the wallflower group the stamens may be numerous.[1] It is hardly within the scope of the present chapter to say anything regarding the causes of the conditions

[1] It is proper to mention that other explanations of the existence of two short outer stamens in *Cruciferæ* are known to botanists. That here given appears, however, to be equally acceptable with more elaborate theories of this condition.

or of the agencies through which the modifications of plants are wrought out. Suffice it to remark that the "law of use and disuse" of organs explains the majority of such cases, by asserting that organs become degraded when they are no longer found to be useful to the economy of their possessors. The degradation of a part is to be looked upon as subservient to the welfare of the animal or plant as a whole, and thus comes to be related to the great law of adaptation in nature which practically ordains that—

Whatever is, is right.

The animal world presents us, however, with more obvious and better marked examples of rudimentary organs than are exhibited by the modifications of flowers—conspicuous as many of these latter instances undoubtedly are. Turning our attention first to lower life, we find amongst insects some notable and instructive illustrations of abortive organs, and also of the ways and means through which the rudimentary conditions have been attained. In the beetle order, the natural or common condition of the wings—which in insects typically number four—is that whereby the first pair becomes converted into hardened wing-cases, beneath which the hinder and useful wings are concealed when at rest. Now, in some species of beetles we may meet with certain individuals with normally developed wings; whilst in other individuals of the species we find the wings to be represented by the merest rudiments, which lie concealed beneath wing-cases, the latter being actually firmly and permanently united together. In such a case the modification has been extreme, but there can be no doubt that the ancestors of the beetles with modified wings possessed fully developed appendages; otherwise we must regard the order of nature as being one long string of strange and incoherent paradoxes. Mr. Darwin has given us some instructive hints regarding the modification of beetles' wings and feet in his remarks on the effects of the use and disuse of parts in the animal economy. Kirby, the famous authority on entomology, long ago noted the fact that, in the males of many of the dung-beetles, the front feet were habitually broken off. Mr. Darwin confirms the observation of Kirby, and further says that in one species (*Onites apelles*) the feet "are so habitually lost, that the insect has been described as not having them." In the sacred beetle (*Ateuchus*) of the Egyptians the tarsi are not developed at all. Mr. Darwin remarks that necessarily we cannot, as yet, lay overmuch stress upon the transmission of accidental mutilations from parent to progeny, although, indeed, there is nothing improbable in the supposition; and, moreover, Brown-Séquard noted that, in the young of guinea-pigs which had been operated upon, the mutilations were reproduced. Epilepsy, artificially produced in these latter animals, is inherited by their progeny. "Hence," says Darwin, "it will perhaps be safest to look at the entire absence of the anterior tarsi (or feet) in Ateuchus, and their rudimentary condition in some other genera, not as cases of inherited mutilations, but as due to the effects of long-continued disuse; for as many dung-feeding beetles are generally found with their tarsi lost, this must happen in early life; therefore the tarsi cannot be of much importance, or be much used by these insects."

The beetles of Madeira present us with a remarkable state of matters, which very typically illustrates how rudimentary wings may have been produced in insects. Two hundred beetles, out of over 500 species known to inhabit Madeira, are "so far deficient in wings that they cannot fly." Of twenty-nine genera confined to the island, twenty-three genera include species wholly unable to wing their way through the air. Now, beetles are frequently observed to perish when blown out to sea; and the beetles of Madeira lie concealed until the storm ceases. The proportion of wingless beetles is said by Mr. Wollaston to be "larger in the exposed Desertas than in Madeira itself;" whilst most notable is the fact that several extensive groups of beetles which are numerous elsewhere, which fly well, and which "absolutely require the use of their wings," are almost entirely absent from Madeira. How may the absence of wings in the Madeiran beetles be accounted for? Let Mr. Darwin reply: "Several considerations make me believe that the wingless condition of so many Madeira beetles is mainly due to the action of natural selection, combined probably with disuse. For during many successive generations each individual beetle which flew least, either from its wings having been ever so little less perfectly developed, or from indolent habit, will have had the best chance of surviving from not being blown out to sea; and, on the other hand, those beetles which most readily took to flight would oftenest have been blown to sea, and thus destroyed." An instinct of laziness, so to speak, alone, or aided by a shortness of wing, developed stay-at-home habits; and such habits would necessarily tend towards the survival and increase of wingless forms. Other Madeiran insects—such as butterflies, moths, and flower-feeding beetles—have well-developed wings, or possess wings relatively larger than they exhibit elsewhere. This observation, remarks Mr. Darwin, is quite in consistency with the theory of the law of natural selection which favours the survival of the fittest. "For when a new insect first arrived on the island, the

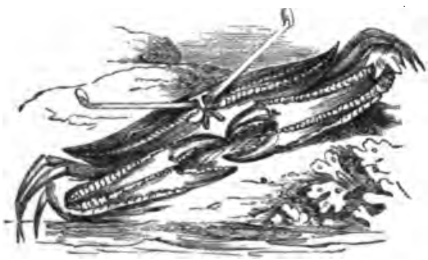


FIG. 25.—SENTINEL CRAB.

tendency of natural selection to enlarge or to reduce the wings would depend on whether a greater number of individuals were saved by successfully battling with the winds, or by giving up the attempt, and rarely or never flying."

Amongst animals of higher rank in the scale than insects, the presence of rudimentary organs is frequently to be demonstrated. What explanation, other than that of degradation and decay owing to disuse, can be offered of the case of the crabs from the Kentucky Cave? Crabs possess compound eyes borne at the extremities of highly movable stalks, these stalks in the sentinel crab (Fig. 25) being extremely elongated. In some of the Mammoth Cave crabs, the stalk remains, but the eye has completely disappeared. As the eyes in such a case could in no sense disappear from any reason connected with injury to the animal, we are absolutely without any reason for their absence other than that of disuse. Professor Silliman captured a Cave rat which, despite its blindness, had large lustrous eyes. After an exposure for about a month to carefully regulated light, the animal began to exercise a feeble sense of sight. Here the modification or darkness had simply affected the function of the eye; in due time the effects of disuse would certainly alter and render abortive the entire organ of sight.

FIG. 26.—APTERYX.

The possession of flying powers is so notable a characteristic of the class of birds, that any exception to this rule, and the want of aërial habits, may be rightly regarded as presenting us with a highly anomalous state of matters. Yet instances of rudimentary wings in birds are far from uncommon; and several groups are, in fact, more notable on account of the absence of powers of flight than for any other structural features. The ostrich, for instance, represents a bird the wings of which are mere apologies for organs of flight, and which are used, as every one knows, simply as aërial paddles. The curious *Apteryx* or Kiwi-kiwi (Fig. 26) of New Zealand, a near relative of the ostriches and running-birds in general, represents a still more degraded condition of the organs of flight, for the wing is reduced in size to an extraordinary degree, and exists in a highly abortive condition; whilst only one complete finger is represented in the hand—other birds, as a rule, possessing three modified fingers. The logger-headed duck of South America has wings so reduced that it can but "flap along the surface of the water," a condition of matters closely imitated amongst ourselves by the Aylesbury duck—although, indeed, the young ducks are able to fly. The wing of the penguin (Fig. 27) is a mere scaly appendage utterly useless for flight, but useful as a veritable fin, enabling it to swim under water with great facility; and of the auk's wing the same remark holds good. In the birds, then, there is ample evidence of deterioration of organs in the rudimentary nature of the wings of many species. How these conditions have been brought about is not difficult to explain in most instances. In New Zealand, where we find a singular absence of quadrupeds, wingless birds—many being extinct — of which the Apteryx is a good example, take the place of the four-footed population. In view of an immunity from the attack of other animals, the ground-feeding habits of these birds would become more and more strongly settled as their special way of life; and in the pursuit of such habits, the wings, seldom used for flight, would degenerate as time passed. The later advent of man, in turn, has exterminated certain races of the wingless birds—such as the *Dodo* (Fig. 28) and *Solitaire* (Fig. 29) in Mauritius and Rodriguez—whilst the wingless and giant Dinornis of New Zealand, and its contemporaries, have probably been hunted to the death of their species, by their human co-tenants of these strange lands.

FIG. 27.—PENGUIN.

The ascent to the quadrupeds brings in review before us still more striking illustrations of the apparently incomplete rendering of the structures of animal life. No better instance of the "rudimentary organs" of the naturalist can be found than in the group of the whales, and more especially in the species from which we obtain the commercial whalebone and oil—the Greenland or Right Whale. This whale possesses no teeth in its adult state, but before birth teeth are found in the gum. These teeth, however, are gradually absorbed, and utterly disappear from the jaws, the adult whale possessing, as is well known, a great double fringe of "whalebone-" plates depending from the palate. The same remark holds good of the unborn young of ruminants, or animals which "chew the cud;" these animals in their adult state possessing no front teeth in the upper jaw, but in their immature condition developing these organs—which, by the way, never cut the gum—only to lose them by a natural process of absorption. Now, here there can be no question of use; and certainly no adequate explanation of their occurrence exists, save that which regards these fœtal teeth as the remnants of structures once well developed in the ancestors of the whalebone whales and ruminants. To this supposition the evidence—avowedly incomplete—obtained from geology gives no contradiction, even if it does not by any means supply the "missing links" in an adequate fashion. We do know that amongst the oldest of the great leviathans of the past was the *Zeuglodon*, of Tertiary rocks, which had teeth developed much in excess of anything we find represented in the dental arrangements of the whales of to-day—a creature this, of

FIG. 28.—DODO.

FIG. 29.—SOLITAIRE.

which, as regards its teeth at least, modern whales are but shadowy reproductions. Whilst under the shelter of great authority, we may declare this ancestor of the whale to have been intermediate in nature between the seals and whales, or between the whales and their neighbours the manatees or sea-cows and dugongs. In either case, the intermediate character of the animal argues in favour of its having been the likely parent of a race dentally degraded in these latter days.

There is little need to specialise further instances of the occurrence of rudimentary organs in the higher animals, save to remark that not the least interesting feature of such cases is contained in the fact that the milk-glands of male animals amongst quadrupeds—organs which exist in a rudimentary condition—have been known to become functionally active and to secrete milk; this peculiarity having been known to occur even in the human subject. Amongst the higher quadrupeds, however, there yet remains for extended notice one special instance of the occurrence of "rudimentary organs," wherein not merely is the nature of the parts thoroughly determined, but the stages of their degradation can be clearly traced through the remarkable and fortunate discovery of the "missing links." Moreover, the case in point, that of the horse, so clearly illustrates what is meant by progressive development or evolution of a species of animals, that it is highly instructive, even if regarded from the latter point of view.

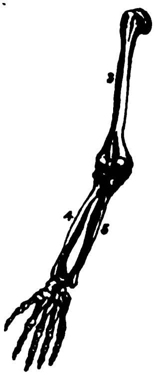


FIG. 30.
BONES OF MAN'S ARM.

When we look at the skeleton of a horse's fore-limb, we are able, without much or any previous acquaintance with the facts of comparative anatomy, to see that it is modelled upon a type similar to that of the arm of man. Were we further to compare the wing of the bird, the paddle of the whale, the fore-limb of the bat, and the fore-leg of a lizard or frog, with the equine limb, we should find the same fundamental type of structure to be represented in all. Thus we find in the arm of man (Fig. 30)—to select the most familiar example from the series just mentioned—a single bone, the *humerus* (3), forming the upper arm: two bones (*radius* [4] and *ulna* [5]) constituting the fore-arm: eight small bones forming the wrist (*carpus*): five bones—one for each finger—forming the palm or *metacarpus*: and five fingers, each composed of three small bones, named *phalanges*, with the exception of the thumb, in which, by a mere inspection of that digit, we may satisfy ourselves only two joints exist. In the wing of the bird (Fig. 31) we similarly find an upper-arm bone or *humerus* (*a*): two bones (*radius* [*c*] and *ulna* [*d*]) in the fore-arm: a wrist (*b*): a thumb (*g*): and two fingers (*c f*, *e d*).

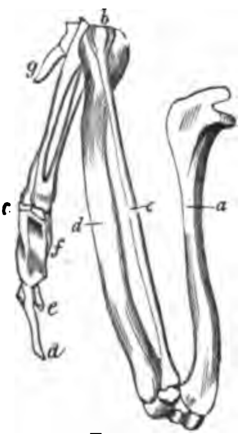


FIG. 31.
BONES OF BIRD'S WING.

Now, turning to the fore-limb of a horse (Fig. 32)—the hind limb being essentially similar in its general conformation, and corresponding as closely with man's lower limb—we find its conformation to correspond in a remarkable fashion to that of man's arm. First, there is the *humerus* (*h*), or bone of the horse's upper arm, concealed, however, beneath the skin and muscles, and being, therefore, inconspicuous in the living animal. The horse's fore-arm, like that of man, contains two bones—*radius* (*r*) and *ulna* (*u*), it is true; but the *ulna* has degenerated in a marked degree, and exists as a mere strip of bone which is tolerably distinct at its upper end, but unites with and merges into the other bone, the well-developed *radius*. The wrist (*w*) of the horse naturally succeeds its fore-arm, but from the fact of the upper arm being concealed beneath the skin and muscles, the wrist is not usually recognised as such. Thus, when a horse chips its "knee," it, in reality, suffers a contusion of its wrist. Man possesses eight bones in his wrist; the horse has only seven, but the equine wrist is readily recognisable as corresponding with the similar region in man. The greatest difference between the human limb and that of the horse is found in the regions which succeed the wrist, and which constitute the palm and hand. Man has five palm-bones: the horse has apparently but one long bone, the "cannon bone" (*m* [1]), in place of the five. Now, to which of man's palm-bones does this "cannon bone" correspond? The anatomist replies, "To that supporting the third or middle finger;" and attached to this single great palm-bone the horse has three joints or "phalanges" (1, 2, 3) composing his third finger. These joints are well known in ordinary life as the "pastern," "coronary," and "coffin bones:" and the last bears the greatly developed nail we call the "hoof."

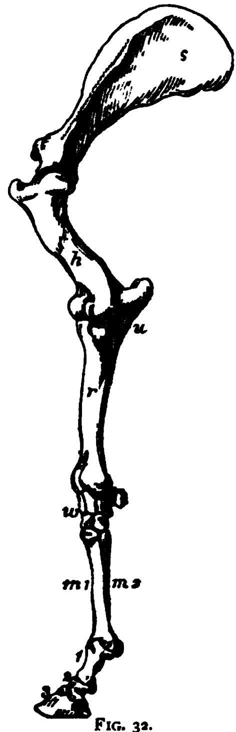


FIG. 32.
BONES OF HORSE'S FORE-LIMB.

Thus the horse walks upon a single finger or digit—the third; and it behoves us to ask what has become of the remaining four—five being the highest number of fingers and toes found in mammals or quadrupeds. We find that, with the exception of other two—the second and fourth fingers—the horse's digits have completely disappeared. The second and fourth fingers have left mere traces, it is true, but it is exactly these rudimentary fingers which serve as the chief clues to the whole history of the equine race. On each side of the single palm-bone (*m*[1]) of the horse's great finger we see two thin strips of bone (one of which is represented at m^2, Fig. 32), which veterinary surgeons familiarly term "splint-bones." (See also Fig. 34, A, *d*, *d*.) But these "splints" bear no finger-bones, and the condition of the horse's "hand," or fore-foot, is therefore seen to be of most noteworthy and curious conformation. It may, indeed, sometimes happen that two small pieces of gristle or cartilage may be found at the base of the splint-bones, and comparative anatomists incline to regard these gristly pieces as the representatives of the first and fifth fingers. The ordinary condition of the horse's hand may be summed up by saying that the animal walks on one well-developed finger—the third—and possesses the rudiments, in the form of the "splint-bones," of other two fingers, the second and fourth. These latter, it need hardly be added, are completely concealed beneath the skin and other tissues of the limb. In the hind limb of the horse (Fig. 33) a similar modification is observed. The thigh-bone (*fe*) and knee-cap (*p*) are readily observed. There is but one toe—the third (1, 2, 3)—supported by a single cannon bone (mt^1); and there are likewise two splint-bones (one depicted at mt^2), representing the rudiments of the second and fourth toes. The horse's heel (*h*), like his wrist, appears out of place, and is popularly named his "hock." The shin-bone (*t*) is the chief bone of the leg, and has united to it the other bone (*fi*), succeeding the thigh, named the *fibula*, and which is seen in man's leg, and in that of quadrupeds at large.

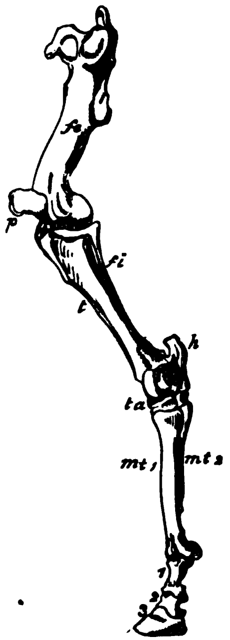


FIG. 33.
SKELETON OF HIND LIMB OF HORSE.

To the eyes even of an unscientific observer, who sees the skeleton of a horse placed in a museum, in contrast with the bony frames of other and nearly related animals, the equine type is admittedly a very peculiar and much modified one. In place of five toes we find but one; and in the matter of its teeth, as well as in other features of its frame, the horse may be said to present us with an animal form which appears as a literal example of Salanio's remark, that—

Nature hath framed strange fellows in her time.

A person of a thoroughly sceptical turn of mind might possibly demand to know the exact reasons for the assumption that the splint-bones of the horse are in reality the rudiments of the fingers we have represented them to be, and might further demand proof positive of their nature. Fortunately, geology and the science of fossils together come to our aid, with as brilliant a demonstration of the steps and stages of the degradation of the horse's fingers as the most sanguine evolutionist could hope to see. From Mother Earth, whose kindly shelter has sufficed to preserve for us the remains of so many of the forms of the past, we obtain the means for constructing a genealogical tree of the equine race, by methods of certain kind, and through the exhibition of fossils, each bearing an impress of its history, which, to use Cuvier's expression, "is a surer mark than all those of Zadig."

Our theoretical journey backwards into the ages begins with the Recent or last-formed deposits—those which lie nearest the outer surface of our earth. The Recent or Quaternary period forms a division of the Tertiary period—that is to say, the latest of the three great epochs into which, for purposes of classifying fossil forms by their relative ages, the geologist divides the rock-formations. The Tertiary rocks, commencing the list, with the last-formed or uppermost strata, begin with the Quaternary or Recent deposits; next in order succeed the older Pliocene rocks; then come the Miocene formations, and lastly succeed the Eocene rocks. These last are the oldest of the Tertiary period, and lie in natural order upon the Cretaceous or Chalk rocks, which themselves belong to an entirely different and anterior (Mesozoic) period in the history of our globe. The youngest or last-deceased of the fossil-horses we meet with, are found in the Quaternary and Pliocene, or the last-formed deposits of the Tertiary system. Between these earlier Pliocene horses and our own Equidæ there are no material differences; and the limbs of these forms may therefore be diagrammatised as depicted in Fig. 34, A, A^1, and B, B^1; the cannon bone in all of these figures being marked *a*; the splint-bones *d d*; the "pastern" and "coronary" bone *b*, *c*, and the "coffin-bone" *f*.

But near the beginning of the Pliocene formations of the Old World, and in the oldest of the Miocene rocks which lie below them, we find a member of the horse family which differs in certain important respects from the horses of the Recent period, and from those of to-day. The fossil horses alluded to are found not merely in Europe, but in the Sewalik Hills in India, and they must therefore have possessed a very wide range of distribution. When first discovered, M. de Christol called this species of horse *Hipparion*, a name which has been still retained for it, amidst that constant alteration in zoological nomenclature which is the labour of the foolish and the sadness of the wise amongst us. What are the chief peculiarities of Hipparion? Briefly stated, in the larger development of the "splint-bones" (Fig. 34, C, C[1], *d*, *d*,), which, according to Owen, must have "dangled by the side of the large and functional hoof (or third toe) like the pair of spurious hoofs behind those forming the cloven foot in the ox." This conformation, continues Owen, "would cause the foot of the Hipparion to sink less deep into swampy soil, and be more easily withdrawn than the more simplified horse's foot." Furthermore, the ulna or bone of the fore-arm, deficient in the horse of to-day, is tolerably well developed in Hipparion.

Backwards in time, and in the older Miocene formations of Europe, another fossil horse was disentombed, and was duly described under the name of *Anchitherium*. This latter horse possesses a completely developed ulna (Fig. 32, *u*) in the fore-arm, and fibula (Fig. 33, *fi*) in the leg; but its chief point of interest lies in the fact that each foot

FORE-FEET.

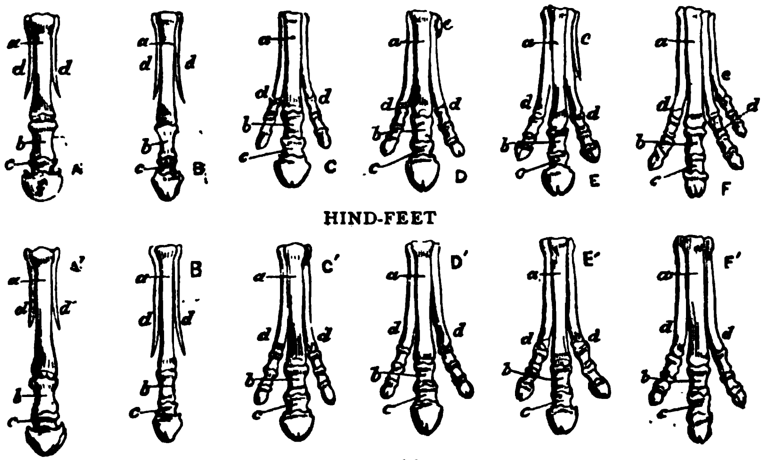


FIG. 34.

possessed three fully developed toes (Fig. 34, D, D[1], *d*, *d*.) which apparently must have touched the ground in walking. Already our splint-bones are seen to better their condition as we pass backwards through the ages, and to appear as the natural supports of well-developed second and fourth toes. Here the geological history of the horse in the Old World may be said practically to end. Modern history assures us that the first horses which peopled the New World, and whose descendants roam over American prairies as the famed mustangs, were imported by the Spaniards at the period of the Mexican conquest. Geology has a more curious tale to relate of the New

World horses and their history, and gives them an antiquity compared with which the events of man's primitive history in either world are but as yesterday. Recent researches amongst the rock formations of Western America, in particular, have shown us that it is to the New World we must look for a perfect pedigree of the horse. For, beginning with the horse of to-day with its splint-bones, we are carried gradually backwards in time to the Pliocene horse of the New World named *Pliohippus* (B, B[1])—a form not differing materially from the living horse, but serving in a very gradual fashion to introduce us to the older *Protohippus*, the New World representative of our own fossil Hipparion (C, C[1]), and in some respects a more typical three-toed horse than the latter. Our own Anchitherium (D, D[1]) corresponds to the next specimen of the New World—*Miohippus* by name; and Miohippus evinces a still more important modification in that it possesses a rudiment of the fifth or little finger (D, *e*) in addition to the second, third, and fourth digits with which the fore-feet are provided.

The American horses now continue the history of the race in time past without aid or representative from the Eastern Hemisphere, in so far, at least, as the latest research has shown. To Miohippus succeeds the *Mesohippus* (E, E[1]) from the American Miocene, which has three well-developed toes, and in addition shows the rudiment of the little finger (E, *e*) of the fore-feet (seen also in Miohippus, D, *e*) in an enlarged condition. Passing to the Eocene formations, the oldest series of the Tertiary rocks, we meet with the next step in the form of the *Orohippus* (F, F[1]), in which the little finger (*e*) appears as a veritable member of the hand, the hind feet still possessing three well-developed toes only: whilst, consistently with the development of the toes, the ulna of the fore-arm and fibula of the leg appear as bones of legitimate size, and present a striking contrast to their rudiments in the horse of to-day. The last discovered horse is from the oldest of the Eocene beds; it has been appropriately named *Eohippus*, and presents us with four complete fingers (second, third, fourth, and fifth) on the fore-feet, and a rudiment of the first finger as well; with a trace of the fifth toe of the hind feet—this last member being, as we have seen, unrepresented in any of the other forms. When the Chalk rocks shall have yielded up their fossil horses, it is consistent with logic and reason to expect that the primitive stock of the horses will be discovered with its complete provision of five toes, and its corresponding modifications of form.

To what conclusions, of reasonable kind, do these stable facts regarding the pedigree of the horse naturally lead? The answer is towards a belief in the slow and progressive modification and evolution of the one-toed modern horse from a five-toed ancestor. This process of modification must, of course, have affected its entire frame, but it is sufficient for our present purpose to point out that in the structure of the foot alone we discern the evidence for evolution as clearly as in the entire organisation of the animal. An increase of speed, and obvious advantage over its enemies, would be gained by the horse, as its toes grew "small by degrees and beautifully less;" and the single-toed race has thus practically come to the front in the world of to-day, as the plain and favourable result of the work of degradation amongst its digits. It may likewise be mentioned, that the conclusions of evolution and geology are strengthened by the evidence of *teratology*, or the science of abnormalities. Occasionally horses are born with several toes; this fact being explicable only on the idea of "reversion" to a multiple-toed ancestry.

Two bony shreds or rudiments thus lay the foundation of a grave conclusion regarding the horse and its manner of development, and exemplify the adage that great and unlooked-for results sometimes spring from beginnings of apparently the most trifling kind. The "splint-bones" form, in fact, a clue which, when rightly pursued, leads not merely to a knowledge of the evolution of the horse, but to an understanding of the entire scheme of nature. For if evolution is the law of the horse's history, it must logically follow that it represents the scheme of nature throughout: since the uniformity of nature, in which we are bound to believe, and to which we are bound to appeal, would utterly negative the idea that evolution should hold good for the horse, and be inapplicable to any other living thing. Because the missing links are not so completely supplied to us in other cases as in the horse, we are not on that account entitled to assume that the theory of development is invalid. We may not see an oak tree grow inch by inch, but we are as positive as our mental nature will admit, that the oak was once an acorn, and that there has been a progressive growth and increase which might not be apparent to us were we to watch the tree for weeks together. Applying this reasoning to the case before us, it would be as illogical to deny that the order of nature was that of development, as to insist that the oak was created as it stands. The extent of human knowledge, and the duration of human existence, are together inadequate to enable us to discern the progress of this world's order after the fashion whereby, from a lofty elevation, we may trace every winding of a stream. But the probabilities of the case are as overwhelmingly for progressive development, as the direct evidence at hand—exemplified by the horse's pedigree—tells against special and independent creation having been the way of developmental law in the making of the world and its living things.

VI.

THE EVIDENCE FROM THE TAILS, LIMBS, AND LUNGS OF ANIMALS.

THE extreme respect occasionally paid by the scientific investigator to the merest rudiments of parts and structures in animals and plants, or to apparently insignificant phenomena in the physical universe around us, naturally presents a source of wonder and curiosity to the uninitiated mind. Circumstances which to the latter appear "trifles light as air," may in truth afford "proofs of confirmation" of the strongest character to the man of science. He has learned from the successes of the past, the wisdom of seeing a possible clue to some of the deepest of nature's problems in the veriest byways and in the most unlikely paths into which his researches may lead. The connection of one fact with another may not at first sight be apparent; and the isolated truth may remain, for years, a detached fragment of knowledge, possessing no evident relationship with the arranged facts constituting the main body of the science. But the patience of science must be equal to its hope; and the experience of the past has taught us many a lesson regarding the real value of facts which seemingly were of little import as year by year they remained disconnected and solitary offshoots of the tree of knowledge. Thus one of the first precepts of scientific inquiry is that which inculcates the wisdom of gathering up the fragments which deep research often leaves behind after its "golden reaping" is past and over. For a second harvest of veritable treasures may not unfrequently reward the patient searcher in science-pastures, after the larger toil has apparently left no corner of the field of inquiry unexplored. The application of the foregoing commonplaceisms is nowhere better exemplified than in many facts supporting evolution which have been elicited from quarters of the most unlikely nature, and from natural-history details which, in former years, might have been regarded as antagonistic to the first principles of the development theory. One of the most convincing circumstances of the general truth of evolution, indeed, consists in the amount of spontaneous support which has flowed towards this theory from all directions in biology; whilst, in turn, the theory of development has strengthened its own case by affording the only rational explanation of hitherto unexplained facts, and in no less degree by supplying the theoretical connection required to connect detached facts with the main body of scientific knowledge.

A popular excursion into the domain of comparative anatomy will present us with several apt illustrations of these remarks, and will serve to prove the truth of the assertion regarding the import to science at large of the veriest "odds and ends" in natural-history trifles. Of such "ends," in one sense, the tails of fishes may be said to present us with examples of the most literal kind. The class of fishes unquestionably presents an interesting field of inquiry to zoology of the most popular nature. There might possibly exist, however, a shade of hesitation on the part of even enthusiastic students of fish-lore, in affirming the truth of the assertion that in the tails of fishes we may perchance find a study of more than usual interest. These structures are unquestionably elegant enough in their way, and, whether as constituting the propelling agents or the steering-gear of their possessors, claim a just share of zoological attention. But that on the caudal appendages of fishes we may presume to "hang a tale" of the probable origin and evolution of the race at large, is an expectation by no means warranted on a brief review and consideration of the apparently trivial nature of the subject. In the history of scientific speculation, however, "tails" have played more than one prominent part. On more than one occasion a theory of tails has been gravely discussed and hotly debated; and it is indeed difficult to assign a reason why the apparent insignificance of the subject should disguise and conceal its real importance. Possibly owing to the deterioration of the caudal region in the human subject, the importance of the "tail" in lower life acquires thus a tendency to become thoroughly overlooked. Were a spider monkey (Fig. 35), however, capable of forming and expressing an adequate opinion on the value of his tail, consisting, as it does, of some

FIG. 35.—SPIDER MONKEY.

thirty-three joints, our estimate of tails in general might undergo a complete revolution. Such an appendage constitutes a veritable fifth hand to that agile denizen of the South American forests. Grasping the bough of a tree with its prehensile tip, he is enabled to swing himself hither and thither, with his hands and feet free and ready for action in any desired direction. He might be inclined to regard his higher neighbours, in which the tail is reduced to a mere rudiment, as degenerate and reduced creatures when compared with himself and his terminal organisation—so much in thoughts and thinking, as we all know, depends upon one's special point of view.

It is, of course, a patent fact to any one who will take the trouble to compare the backbone of man with that of a spider monkey, or indeed with the spine of well-nigh any other quadruped that the four small bones forming the end of the human spine, and collectively named the *coccyx* (Fig. 36), represent a rudimentary tail. These bones are seen to be degraded and deteriorated in structure when compared with the other joints of the spine (or vertebræ) with the typical structure of which they undoubtedly correspond. As any tail is merely the hinder extension of the vertebrate spine, so the coccyx, representing in its feeble way the terminal part of man's spine, is certainly a veritable appendage of the kind in question. Man is, however, not the only animal in which degradation of the tail exists, and is propagated by descent as a natural condition of animal existence. The Manx cat has a truly rudimentary tail in this latter aspect; certain higher monkeys (*e. g.*, orang, chimpanzee, and gorilla) possess the merest traces of this appendage; and tailless varieties of sheep are known, the latter being well exemplified by a Chinese breed in which, as Mr. Darwin, quoting from Pallas, tells us, the tail is reduced "to a little button, suffocated in a manner by fat." It should also be remembered that, in lower life, tails of considerable length may dwindle and disappear, leaving their possessors as abso-

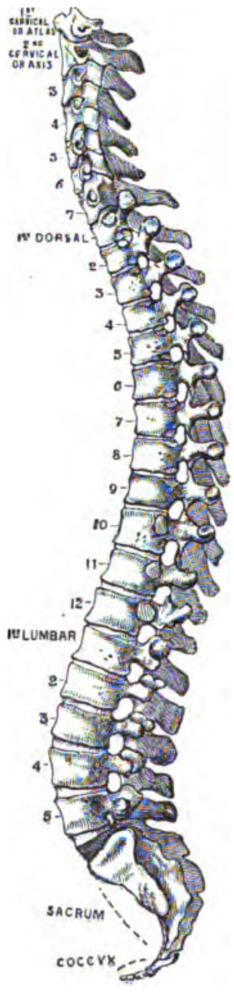
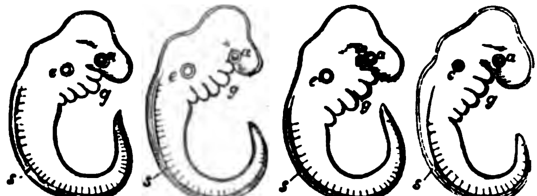


FIG. 36.
SIDE VIEW OF HUMAN SPINE.

lutely tailless as man. One has but to compare the young crab with the adult, or the fish-like tadpole with the frog (Fig. 48), to witness a most typical case of the disappearance of a tail. And it is worth remembering that the frogs have the advantage of humanity in point of antiquity; since the advancement of the tailed tadpole race to become the tailless frogs of to-day must have taken place, according to geological evidence, long ages anterior to the advent of the "imperial race" of man.

But if so much may be proved and said regarding the rudimentary nature of "tails," it must also be borne in mind that the opposite case of a special development of the tail in man is by no means unknown. Occasionally in the human subject a short but free tail is found to be developed, this fact constituting at once a surgical abnormality and a physiological "reversion" to an ancient order of things. Let us consider for a moment what development teaches us concerning the exact place assumed by the end of the spine in higher animals. Primarily, we are struck by the close resemblance to each other presented by the embryos or young of vertebrate animals (Fig. 37) in their earlier stages of development. Even Von Baer himself, an authority in matters relating to embryology, said of this likeness that "the embryos of mammalia, of birds, lizards, and snakes, and probably also of Chelonia (tortoises and turtles), are, in their earliest states, exceedingly like one another, both as a whole and in the mode of development of these parts; so much so, in fact, that we can often distinguish the embryos only by their size. In my possession," he continues, "are two little embryos in spirit, whose names I have omitted to attach, and at present I am quite unable to say to what class they belong. They may be lizards, or small birds, or very young Mammalia, so complete is the similarity in the mode of formation of the head and trunk in these animals. The extremities, however, are still absent in these embryos. But even if they had existed in the earliest stage of their development, we should learn nothing, for the feet of lizards and mammals, the wings and feet of birds, no less than the hands and feet of man, all arise from the same fundamental form." The close likeness between vertebrates in their early stages of growth, so plainly lescribed in Von Baer's words, extends to the caudal or tail-



A B C D

Pig. Calf. [Fig. 37.] Rabbit. Man.

region amongst other parts and details of structure. It is not more surprising, in truth, to find that man in early life possesses an undeniable tail (Fig. 37, D) than to discover that he is provided at the same period with a series of clefts and arches in the side of his neck (Fig. 37, *g*) corresponding to the gill-clefts and gill-arches of fishes and other gill-possessing vertebrates. Like his gill-clefts, man's caudal appendage gradually becomes abortive as development proceeds; but he retains the rudiment of his tail, whilst the gill-clefts entirely disappear. Nor is this all. When the coccyx of man (Fig. 36) is examined in its ordinary and adult condition, it is found to be provided with the merest rudiments of muscles, one of which corresponds to a very large extensor muscle developed in the tail of many quadrupeds—just, indeed, as man possesses a representative rudiment of the muscle by which the dog and horse shake their coats, as well as thoroughly useless rudiments of the muscles which move the ears of his lower neighbours. Thus man's coccyx furnishes important evidence of his origin, and the isolated facts of human anatomy regarding the tip of the human spine fall naturally into the service of the theory of development which relates man in the most intimate fashion to lower but no less wondrously formed creatures.

With the opinions of that learned Scottish judge, Lord Monboddo, respecting the causes of disappearance of the human tail, most readers are well acquainted. In his day Lord Monboddo was esteemed the shrewdest of men; and, despite the fact that his theory of the disappearance of man's tail through the friction of pressure produced by the sitting posture has been a stock subject with those who can afford to treat such subjects in a flippant manner, one may be excused for suspecting that his lordship certainly meant what he wrote. It is extremely interesting, therefore, to find that Mr. Darwin, strengthening himself by observation on the manner in which certain apes dispose of their rudimentary tails, comes to the conclusion that the theory of the tail's disappearance through friction "is not so ridiculous as it at first appears." A certain monkey, a species of Macaque, possesses a short tail composed of eleven joints, whilst its tip is very flexible and sinewy. In the sitting posture this tail may prove a decided inconvenience to the animal. It is frequently bent under the body, and a peculiar curve exhibited by the tail leads to the belief that the tail had originally been bent round by the will of the animal, and so disposed as to prevent being pressed into the ground. One result of this adaptation to the sitting posture is that the tail is rough and hard; and as we know from positive evidence that the mutilations and injuries of the parent may be inherited by the offspring, it is conceivable that the short tails of many monkeys indicate the results of degeneration from the effects of gradual and inherited mutilation. This idea is strengthened in a very material fashion by the consideration that in other species of Macaques the tail has actually become thoroughly abortive. It is difficult or impossible to explain, save on the theory of gradual modification affecting species in different ways and at different rates, why one species of monkey should have a fairly developed tail, whilst in another and nearly related species the tail has well-nigh disappeared. This dissertation on the tail as represented in human existence, may preface the brief dissertation on the tails of fishes, the consideration of which in its own way teaches us a lesson in evolution equally plain with that drawn from the confines of quadruped existence.

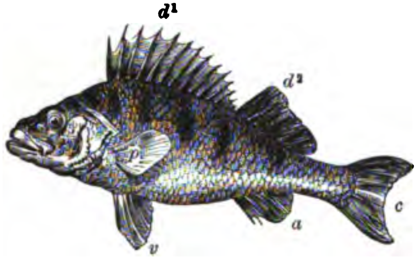


FIG. 38.—PERCH.
*d*¹ *d*², dorsal fins; *c*, caudal fin; *a*. anal fin; *p*, pectoral, and *v*, ventral fin.

The tails of fishes, as everyone knows, are set vertically (Fig. 38, *c*), so that the flat surfaces of the tail-fin correspond with the sides of the body. The fish in this respect differs materially from the whale (Fig. 39) or dolphin, in which the tail is placed horizontally, or across the body. When a review of the tails of fishes is attempted, two very distinct forms of this appendage are discerned. In most fishes the tail may be described as symmetrical when unforked (Fig. 38), or as possessing its halves of equal size when forked (Fig. 40). But in other fishes, and most notably in such fishes as the sturgeons, sharks, and dog-fishes, the upper half of the tail is seen to be disproportionately developed when compared with the lower half. In such a fish as the fox-shark (Fig. 41) or thresher—both names, indeed, being derived from the peculiarity in question—the upper lobe of the tail appears relatively enormous when compared with the lower half. Such are the external appearances of fishes' tails; and from their

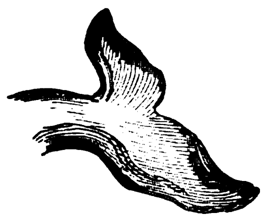


FIG. 39.
HORIZONTAL TAIL OF WHALE.

FIG. 40.—FISH SHOWING AN EQUAL-LOBED TAIL.

aspect when casually regarded we might seem fully justified in saying that but two kinds of tails were developed in the fish class, namely, equal and unequal tails. We must, however, inquire as to the verdict which comparative anatomy, with its deeper research into the structure and composition of parts, has to pronounce on the likenesses or differences which the superficial view discovers. The result of such an inquiry shows us that the tail of a fish, in Othello's words, may be said to—

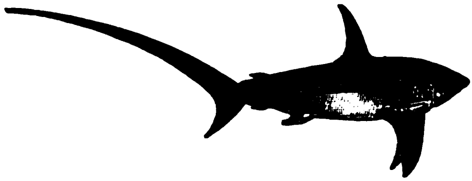


FIG. 41.—THRESHER OR FOX-SHARK.

> Beguile
> The thing I am by seeming otherwise;

since we shall find that the tail of equal shape and conformation is certainly not what it seems; and that, moreover, it possesses a singular relationship to its unequal neighbour. When the bony framework consisting of the end of the spine, which supports the tail, is duly examined in certain fishes, such as the *Polypterus* of African rivers, the spine is seen to terminate in such a fashion that the rays of the tail-fin are divided into two equal portions. In this case the tail is both apparently and really symmetrical. But such a state of matters is comparatively rare. The salmon, as every one knows, has to all intents and appearances a tail which is perfectly symmetrical and equal. Yet when we inspect the skeleton of the salmon's tail (Fig. 42), we find a very obvious want of symmetry. The extremity of the tail is bent upwards, as depicted in the illustration, so as to give a greater preponderance of spine (*s s*) to the upper half, and the symmetry of the tail is preserved simply through the lower fin rays being more numerous and longer than the upper ones. In those fishes (Fig. 41), on the other hand, in which the tail is of unequal conformation, even in external appearance, the upper half attains its greater development from the spine extending boldly upwards, and from the inferior and rudimentary development of the rays and elements of the lower half of the tail. Thus summing up the knowledge regarding fishes' tails which comparative anatomy supplies, we find that only a few fishes possess really symmetrical tails—that is, tails in which the spine terminates in the middle line, and in which the fin-rays are given off

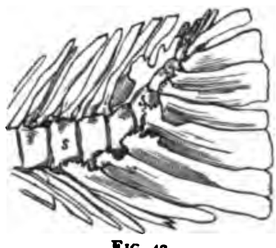


FIG. 42.
SKELETON OF SALMON'S TAIL.

in symmetrical array. And we also discover that in most fishes with apparently equal tails, the spine is really unsymmetrical (Fig. 42), and projects into the upper half—a condition of affairs more visibly exemplified in certain fishes of which the sharks (Fig. 41) and dog-fishes are the best known examples.

The inferences and conclusions regarding the general development of the fish-class which may be deducible from the brief consideration of the structure of the tail in these animals, will be apparent if we venture to trace the development of the tail, and to take a wide survey of the succession of the fishes in time, as represented in the records of the rocks. It is perfectly clear, to begin with, that the tails of all fishes are modelled upon one and the same type. In so far as the prevalence of one modification of a type over another may be said to indicate the primary form of the type, we may hold that the fish-tail begins as a straight appendage, to which must be assigned the place of honour, as probably the first, most primitive, and least modified form of the fish-tail, whilst to this straight condition succeeds the unequal variety. And the story told by development very plainly endorses this statement. All fish-tails, whatever their ultimate and adult form, exhibit the unequal type as their second well-defined condition. The equal appearance of the tail of the vast majority of fishes is thus proved beyond doubt to be a third and comparatively modern innovation, so to speak, in the matter of fish history.

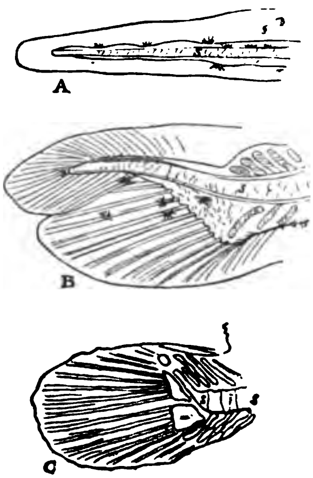


Fig. 43.
Development of the Tail in Flounder.

If we appeal to the researches of Alexander Agassiz on this point, we may learn much that is instructive and edifying on this curious question. In the development of the flounder, for instance, the soft rod, named the *notochord*, which at first does duty for the spine, is seen to possess a straight extremity (Fig. 43, A *s*); and the embryonic or first-formed tail-fin is simply rounded in shape. Very soon the tail end of the notochord becomes bent upwards, and carries up with it in its progress the primitive tail-fin. At this stage (Fig. 43, B) the permanent tail-fin becomes marked out and defined from the primitive fin, and in due course, and even before the spine itself has become developed, the young flounder possesses an unequal tail. In this stage the young flounder, indeed, possesses a tail-fin resembling the unequal tail seen permanently represented in the ganoid fishes of to-day (*e.g.* Sturgeon). The permanent tail-fin appears almost like a second anal fin (Fig. 43, B)—the anal being the fin (Fig. 38, *a*) situated in the middle line of the fish below. As the spine develops, it is formed behind around the bent-up end of the notochord (Fig. 43, C); and as development is completed, the perfect and still unequal tail-fin of the flounder appears under a symmetrical guise, from its encroaching upon and ultimately replacing the primitive fin. It is a noteworthy fact that certain of the stages exhibited by the tail of the flounder and of other fishes during development, present, as already remarked, the closest possible likeness to the permanent condition of the tail in some of those fishes in which the tail is markedly unequal in form.

After such revelations from the laboratory of the zoologist, we may be prepared to discuss the validity of the conclusions to which the evolutionist is led—namely, that the unequal tail-fin is the primitive form of that appendage, and that this tail, in its turn, was preceded by a straight or rounded termination to the body, represented by the first stage of development in the flounder (Fig. 43) and in other fishes. The history of the individual fish and its tail, in other words, presents us with a short recapitulation of the evolution of the whole fish race and the tails thereof.

Such a speculation seems perfectly consistent with the facts of the case, provided we admit that, as the scientific world is well agreed, the development of an animal presents us with a panorama of its descent. Regarded otherwise, the ever-varying and often inexplicable succession of stages in animal development simply appear before us as a collection of phenomena without any conceivable meaning or interpretation. But if in the record of fish-development it may be accepted as true—firstly, that the unequal-lobed tails belong to the oldest members of the class; and, secondly, that the great bulk of our modern fishes with even tails are to be regarded as being "foremost in the files of time," and relatively new-comers on the stage of life—it may be further asked if any counter-proof to these assertions is capable of being produced. Fortunately, in the science of fossils we possess a means for verifying and substantiating our conclusions. Suppose that we hark backwards in time, and try to discover the exact succession and order in which the fishes have appeared, as indicated by their fossil

FIG. 44.—LANCELET.

history. Let us inquire, for instance, regarding the nature of the oldest fishes, and trace the piscine race downwards to existing times, as completely as the scattered pages of nature's records will admit. If we discover that the *succession of fish-tails in time* corresponds with the *order of their development to-day*, we may then be certain that the history of the individual repeats the history of its race.

Of the very lowest fishes, it must firstly be remarked, we possess no traces or record in a fossil state. These democrats of the fish class are represented by the existing lancelet (Fig. 44), a tiny fish about an inch and a half long, with a soft and perfectly transparent body; and by the lampreys (Fig. 45) and hag-fishes — the latter found boring their way into the bodies of cod and other fishes by means of a single large tooth borne on the palate. The lancelet, lampreys, and hag-fishes possess no hard parts which could have been preserved in a fossil condition. Yet, from all considerations regarding their lowness of structure, we are forced to conclude that these fishes possess an immense antiquity, and probably represent the primitive founders of the entire fish class.

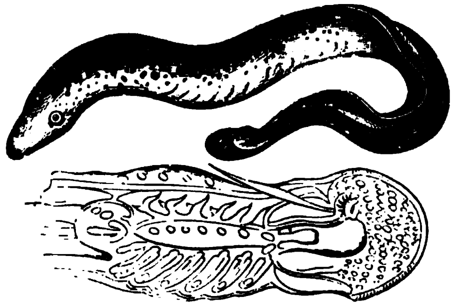


FIG. 45.—LAMPREY AND ITS BREATHING APPARATUS.

The first rocks in which the fossil remains of fishes occur are the Upper Silurian strata. These first traces at once of fish and vertebrate life consist of the fin-spines, &c., of fishes evidently allied to our existing sharks—fishes which possess, as we have seen, the primitive type of the unequal tail. Throughout the succeeding ages of the Palæozoic period—a period including in its later epochs the Old Red Sandstone, Coal, and Permian formations—the type of fish-tail remains practically unaltered, and presents us with the unequal form. Nowhere is the unequal tail more typically seen than in the famous fishes of the Old Red Sandstone (Fig. 46), which, clad in a stout shield-like armour of "ganoid" scales, like our living bony pike (*Lepidosteus*) and sturgeon, must have presented well-nigh impregnable fronts to their adversaries. As Owen remarks, "the preponderance of heterocercal (unequal-tailed) fishes in the seas of the geological epochs of our planet is very remarkable; the prolongation of the superior lobe (or upper half) characterises every fossil fish of the strata anterior to and including the Magnesian Limestone (Permian rocks); the homocercal (even-tailed) fishes first appear above that formation, and gradually predominate until, as in the present period, the heterocercal (unequal-tailed) bony fishes are almost limited to a single ganoid genus (*Lepidosteus*)."

Not until we pass far into the Mesozoic rocks, and arrive at the Chalk, do we meet with fossil representatives of the familiar fishes (such as our herring, salmon, cod, &c.) which swarm in the seas of to-day, and which, as we have seen, possess apparently equal tail-fins. After the beginning of the Mesozoic period, we discover that the ganoid and other unequal-tailed fishes begin to decline in numbers, many groups becoming wholly extinct; whilst only a comparatively few representatives of these early fishes remain in our seas of to-day to represent, like "the last of the Mohicans," their plentiful development in the oceans of the past.

FIG. 46.—PTERICHTHYS, A FOSSIL FISH (OLD RED SANDSTONE).

The geological evidence, then, reads very strongly in favour of the evolutionist's views concerning the great antiquity of the unequal-tailed fishes. We may see, theoretically, the first beginnings of the fish-tail paralleled by the first stage of the modern flounder (Fig. 43, A), and by the permanent condition of the living lancelet and lampreys; presenting us with a symmetrical end to the body, but with no very characteristic or definite tail. Next in order in point of time, come the ganoid fishes (Fig. 46), and the representatives of the sharks (Fig. 41), skates, and rays, with tails of the truly unequal conformation, the spine bending upwards into the upper half of the tail—an era in the development of the fish group represented by the second stage of the flounder (Fig. 43, B), when the extremity of the back-bone is seen to undergo a similar alteration in growth. Ultimately we attain in the Chalk to the modern order of things, and find therein the first appearances of fish-tails of the modern and equal type—a conformation which, as we have seen, really retains, under the guise of an outward symmetry, the evidence (Figs. 42 and 43, C) of its connection with the unequal tail of long ago. Thus perfectly does the geological evidence harmonise with that of development, in showing us how modification and evolution have represented the laws of fish-production. It is only needful, by way of close to such a history, to remark that the laws of evolution and of the production of fishes through descent and modification follow, in their uncompromising application alike to higher and lower life, the boasted impartiality of the legal codes of man. The laws of life, like those of matter, indeed, are absolutely inflexible throughout; and the story of a fish-tail and its development finds the closest parallel in that chronicle through which evolution traces the production and growth of the entire scheme of nature.

From the nature and development of the tails of fishes and of other animals we may pass, by an easy transition, to the subject of limbs, and their modifications. In this latter study we may perchance discover facts and inferences of no less interest than those evolved in our investigation into the history of fishes' tails. The limbs of animals appear before us as out-jutting portions or special outgrowths of the trunk or body proper. That there are limbs and limbs is a very evident fact to any one who considers the wide variations which exist between the similarly named parts in an insect or centipede, a fish, a bird, a whale, a dog, and a man. And even within the limited compass of our own frames, there would appear at first sight to be an essential difference betwixt the arm and leg, and an equally great distinction between the fore-limbs, or "wings," of a bird or bat, and the hind limbs of these animals. A fish, too, might

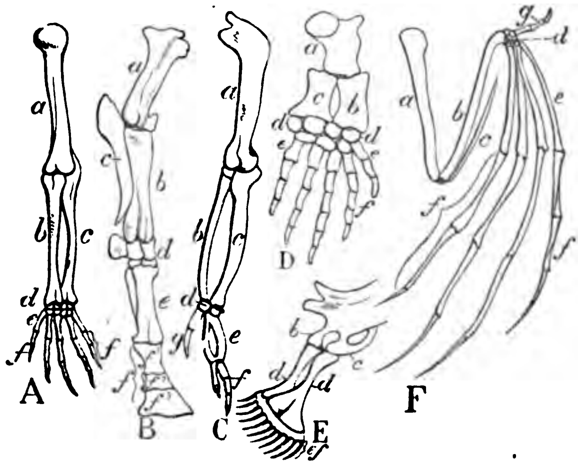


FIG. 47.—FORE-LIMBS OF VARIOUS VERTEBRATE ANIMALS.
A, man; B, horse; C, bird; D, whale; E, fish; F, bat.

popularly be supposed to want limbs; but, as the sequel will show, most fishes possess very distinct representatives of the bodily appendages seen in higher animals, and associated with the movements of the frame. Leaving the limbs of invertebrate animals out of sight for the nonce, we may find that, despite the apparent dissimilarity of form and functions, the limbs of vertebrates present an identity of structure which is literally amazing. A very slight examination of the limbs of a horse would convince us that, roughly regarded, the parts or segments of the fore-limb (Fig. 32) correspond to those of the hind-limb (Fig. 33). There usually exists a degree of correspondence between fore- and hind-limbs which is easily observed, but which, on the other hand, in such animals as bats and birds appears less easy of detection. But, laying aside external appearances as thoroughly unreliable, let us appeal once again to comparative anatomy, and inquire, firstly, into the likenesses and differences between limbs; and secondly, into the nature and manner of origin of these important appendages.

In the arm of man (Fig. 47, A) we find an upper arm bone (*a*), two bones in the fore-arm (*b* and *c*), eight bones in the wrist (*d*), five in the palm (*e*) of the hand, and three in each of the fingers (*f*), save the thumb, which is composed of but two bones. Thus it would seem that in the arm of man there are some three chief segments, namely, upper arm, fore-arm, and hand; and in the lower limb the same elementary divisions, corresponding to thigh, leg, and foot, may be discerned. Man has five fingers, which, reckoning from the thumb side, we may number one, two, three, four, and five respectively; the great toe being similarly the first digit of the foot. In the wing or arm of the bat (F) a type of structure exactly similar to that seen in man's arm is readily perceived. The upper arm (*a*), fore-arm (*b c*), (with one of its bones [*c*] somewhat degraded in size,) the wrist (*d*), the palm (*e*), and the fingers (*f*), are fully represented in the bat; but the four fingers are greatly elongated to support the fold of skin forming the flying-membrane, and the thumb (*g*) is of small size. No doubt can exist, therefore, that the arm or fore-limb of man is exactly similar to that in structure, or, in other words, is "homologous" with the arm or fore-limb of the bat. In the paddle of the whale (D), shortened and modified as that limb may be, we perceive a type of structure exactly corresponding with that of man and the bat—the upper arm (*a*), fore-arm (*b c*), wrist (*d*), palm (*e*), and fingers (*f*), being readily seen when the skeleton of the paddle is even cursorily examined. Of the wing of the bird (C), despite the modification of its wrist and fingers, the same opinion in favour of exact agreement with the human, bat, and whale type must be expressed. Upper arm (*a*) and fore-arm (*b*) are duly represented in the wing; and although but two wrist-bones (*d*), two united (second and third) fingers (*e*, *f*), and a rudimentary thumb (*g*) exist, there can be but one opinion as to the agreement of bird and man in respect of the identity of their fore-limbs. In the horse (B), whilst the limb itself, down to and including the wrist (*d*), exactly resembles in all essential details the limbs already considered, (see preceding chapter, page 90, *et seq.*) we find the fingers reduced to one—the third. Rudiments of the second and fourth fingers, however, also exist, and prove to us the essential similarity of the one-fingered hand of the horse with the five-fingered hands of its higher and lower neighbours.

If we investigated the limbs of reptiles and those of the frogs (Fig. 48) and their kind, we should detect a like agreement in fundamental structure with the limbs of man and his nearest allies—the upper arm (*h*), fore-arm (*r*), wrist (*wr*), palm (*mc*), and fingers being duly represented. The fishes, as the lowest members of the vertebrate group, would, however, present us with grave difficulties in the way of reconciling the structure of their limbs with that of higher animals. Fishes (Fig. 38) possess two sets of fins. These consist of the first set, or *paired* fins—the "pectorals" or "breast" fins (*p*) and "ventrals" (*v*). The second set, forming the *unpaired* fins is placed in the middle line of the body, that is, on the back (d^1, d^2) and on the belly (*a*) of the fish, whilst the tail-fin (*c*) also belongs to the unpaired series. It is evident that the "paired" fins must represent the limbs of other vertebrates, such limbs being invariably developed in pairs. The breast-fins (Fig. 38, *p*) of the fish are in reality its arms, whilst the ventral fins (*v*) represent its lower or hinder limbs. Comparative anatomists are not agreed as to the exact or detailed correspondence of fish-limbs with those of other vertebrates, but that such a correspondence exists no one may doubt, since, were any other proof wanting, the naturalist might point to the fact that the representatives of the limb-girdles (shoulder-bones and haunch-bones) of higher animals are developed in fishes for the support of their paired fins. The "limbs" of fishes, in short, belong to a very primitive type of limb, which, from its early origin and special development in relation to the surroundings of fishes, exhibits but little correspondence with limbs of later forms. But we may thus discover the important fact that the limbs of vertebrate animals are modelled on a common plan, and the task of discovering how such identity may be explained, forms a legitimate subject of further inquiry.

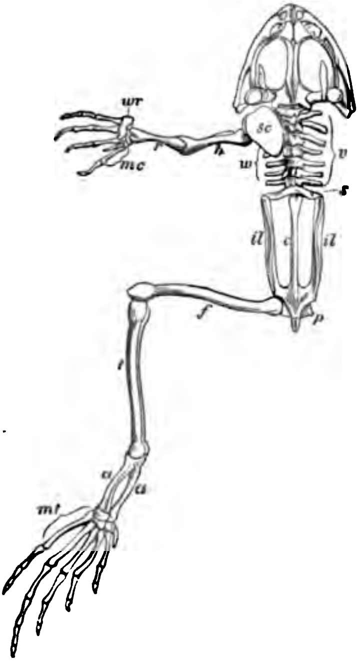


FIG. 48.—SKELETON OF FROG.

A primary remark, of some importance in investigations like the present, would insist on our recognising that a series of deep-seated likenesses in internal structure, such as that presented to our notice in the limbs, is much more likely to be truly accounted for by some natural law of development than by any mere chance production, or by any spontaneous resemblance existing apart from natural affinity. If we assume for a moment the position of a holder of the "special creation" theory, we may form some idea of the difficulties which beset the reasonable imagination in accounting for likenesses of such well-marked character as the limbs of vertebrates exhibit. In each case we should require to postulate a new and special creative act which had, according to no known or conceivable law, modelled these appendages on one and the same type—a system of creation given to the preservation of useless rudiments of once useful structures, instead of simply giving to each animal the exact organs and parts it requires. True, such a method of creation may be conceivable, but nothing more, if we reflect once again upon the extraordinary likeness and on the evident common relationship of the limbs. But this creative theory entirely loses caste and status when placed in contrast with the more reasonable theory of descent. By means of this latter explanation we account for limb-likeness on the principle of natural inheritance, and on the relationship, through descent, of the animals which bear the related limbs. We thus see in limb-likeness merely the natural result of descent from a common ancestor or ancestors, in which the fundamental limb-type was developed. The law of likeness, whereby the offspring tend to resemble the parent, in fact demands common limb-likeness as the natural heritage of all vertebrate animals, and presents the theory of descent as the only natural solution of the query, "Why are limbs modelled on one and the same type?"

As Darwin himself remarks, "what can be more curious than that the hand of a man formed for grasping, that of a mole for digging, the leg of the horse, the paddle of the porpoise, and the wing of the bat, should all be constructed on the same pattern, and should include similar bones in the same relative positions? How curious it is, to give a subordinate though striking instance, that the hind feet of the kangaroo (Fig. 49, A), which are so well fitted for bounding over the open plains—those of the climbing leaf-eating koala, equally well fitted

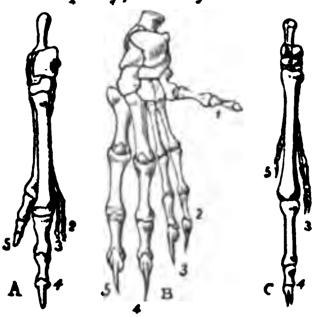


FIG. 49.—FEET OF MARSUPIALS.

for grasping the branches of trees—those of the ground-dwelling insect or root-eating bandicoots—and those of some other Australian marsupials (Fig. 49, B, C)—should all be constructed on the same extraordinary type, namely, with the bones of the second and third digits extremely slender and enveloped within the same skin, so that they appear like a single toe furnished with two claws. Notwithstanding this similarity of pattern, it is obvious that the hind feet of these several animals are used for as widely different purposes as it is possible to conceive. The case is rendered all the more striking by the American opossums, which follow nearly the same habits of life as some of their Australian relatives, having feet constructed on the ordinary plan. Professor Flower, from whom these statements are taken, remarks in conclusion: 'We may call this conformity to type, without getting much nearer to an explanation of the phenomenon;' and he then adds, 'But is it not powerfully suggestive of true relationship, of inheritance from a common ancestor?'" To say that things were simply created so after a creative plan, may be a confession of faith; it is in no sense a scientific explanation with which the mind may grapple so as to arrive at its true significance.

But the theory of descent goes still further. It also supplies an answer to the obvious question which awaits the naturalist, "How are the variations seen in the limbs of vertebrates to be accounted for?" Admit that the varied limbs of vertebrates are but so many modifications of a common type, and that, as such, they were derived from their ancestors, to what process do they owe their subsequent modification to the varied wants and ways of life of their predecessors? The agreement in fundamental structure, as we have seen, is the result of inheritance; to what law of life do we owe the variations in function the limbs exhibit? The answer to this query lies in a single word—*adaptation*; that is, the modification of the primitive type of limb for the special circumstances of each animal's life. The essential principle and strength of evolution, consists in its ability to show, firstly, that alteration and modification of an animal's structure take place according to its requirements, and as determined by the surroundings of its life; and secondly, that such variations as are favourable or profitable will be preserved. Such modifications as would fit a limb for swimming or for flight might take place without any violent or sweeping alteration of the limb-type as a whole. We know as a fact, that the skeletons of some domesticated and artificially bred animals, such as the pigeons, are liable to alteration and modification of structure without change of the type of bony framework; and so with the limbs, which, as mere appendages, are infinitely more susceptible of alteration and adaptation to new ways of life. Thus is illustrated the principle of "natural selection," which constitutes the key-note of Darwinism, and which contends for the preservation of those variations and alterations in structure favourable to the preservation of the animal and its race; such favourable variations giving it an advantage in the "struggle for existence." This principle satisfactorily enough accounts for the modification of limbs to suit the varying habits of life which from time to time were assumed by Vertebrate animals, as the new races and groups sprang into existence by the modification of the older and more primitive stocks. And the presence of the varied scheme of the Vertebrate life of to-day—the active bird, the crawling serpent, the lithe fish, the fleet steed, the aërial bat, and even the erect ruler of the universe himself—in this view, appears but as a testimony to the operation of a great law of nature, which decrees that the newer and stronger shall possess the earth, whilst the weak and primitive are at the same time prevented, and perhaps wisely, from cumbering the ground.

The subject of the origin of limbs, however, still awaits our brief study. At various periods in the history of comparative anatomy, the original nature of limbs has formed a subject regarding which very diverse opinions have been expressed. Owen long ago regarded limbs as corresponding to processes or appendages of ribs; Maclise represented them a little later as modified ribs; and other authorities have propounded theories in which the limbs are regarded as

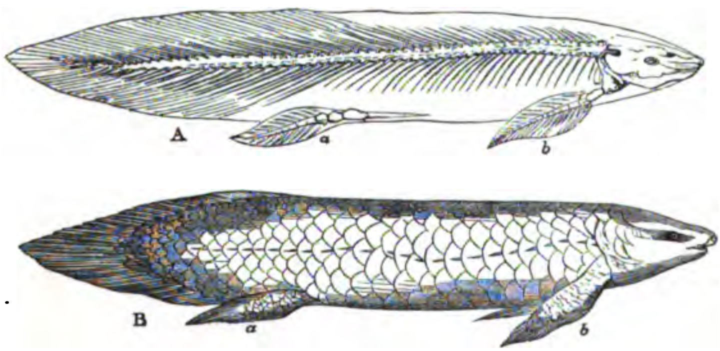


FIG. 50.—THE CERATODUS OR BARRAMUNDA.
A, skeleton showing *a* the ventral, and *b* pectoral fins; B, the fish itself.

corresponding to outgrowths from a peculiarly modified gill arch, the latter structure forming the supporting "girdle" of the limbs—or, in the case of the fore-limb, the "shoulder." Recent researches into the development of the fins of fishes—to which we naturally turn for the most primitive form of limb extant—appear to lead to the declaration that there is no real difference in nature to be perceived between the "paired" and "unpaired" fins (see Fig. 38). The paired fins of the dog-fishes and sharks are known to arise as special developments of a single long and continuous fold existing in each side of the young fish; and the unpaired fins arise from folds of like nature. Thus, if the history of the individual may again be held to explain the evolution of the race, then we may conceive of the first limbs having been developed as a pair of long and unbroken side-fins, which ultimately became detached or broken up to form the paired fins as we see these organs in the fishes of to-day. When the simplest types of limbs in fishes are examined, as for example in the *Ceratodus* or "Barramunda" of Australian rivers (Fig. 50)—the native "salmon" of the colonists—the primitive nature of such fins appears to accord well with the idea of their origin and formation as above described. In *Ceratodus* the skeleton of the limbs (Fig. 50, *a*, *b*, and Fig. 51) appears as a simple many-jointed rod of gristle (Fig. 51, *a*), to the sides of which the equally simple fin-rays are attached. It is equally interesting to find that the lowest and presumably the oldest and most primitive fishes —the lancelet (Fig. 44) and the lamprey (Fig. 45) tribe—are absolutely destitute of paired fins or limbs. These latter fishes may thus be regarded as presenting us with a representation of those early stages in piscine existence, before the limbs became specialised, and when the unpaired and median fins alone represented the organs of motion. That both pairs of limbs were probably developed from one and the same structure is rendered more than probable when we discover that in some fishes the pectoral and ventral fins exactly resemble each other—such a likeness being well seen in the somewhat remarkable fish, allied to the sharks, &c., and known as the *Chimæra*, or "King of the Herrings." The development and growth of the paired fins or limbs became localised, and thus brought about the separation of the limbs and their distinction from the continuous side-folds which gave them birth; whilst the growth of the unpaired fins, on the other hand, continued throughout the entire length of the fold, and resulted in the production of the back, tail, and anal fins as we find them to-day. Amidst much speculation and not a few theoretical considerations regarding the nature of the limb-girdles or supports, which it must be left to future research to substantiate or nullify, there still remains to us a large share of true and exact philosophy in what is definitely known regarding the genesis of limbs. In such a study we discern a new phase of the ever-recurring watchwords of the evolutionist, "modification" and "descent." And we are led also to note that in the past history of even the most familiar structures of

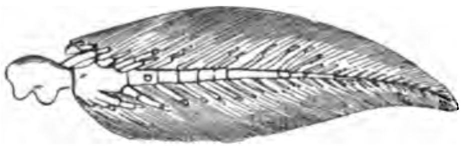


FIG. 51.—FIN OF CERATODUS.

animals may be contained a veritable romance of science. For certainly no more startling or unlikely supposition than that of the common nature of the arm, the wing, the fin, the paddle, and the limb, could well be broached. Yet, as the context may have shown, the facts of life bear out the romance with which even a technical but interesting study may be shown to be invested; and the truths of comparative anatomy are thus shown to be stranger indeed than the creative fictions of former years.

If the tails of fishes may be literally deemed "ends" in the most literal sense, there yet remain one or two cases of "odd" structures in fishes and in other animals, the investigation of which may serve to strengthen those conclusions respecting the validity of the development theory at which we have already arrived. One of the most peculiar structures found in fishes is the "air-bladder," "swimming-bladder," or "sound," as it is variously called. From the walls of the swimming-bladder of the sturgeons the well-known "isinglass" is prepared. The air-bladder exhibits exceedingly diverse forms in the class of fishes, and in truth presents the upholders of the "special creation" theory with one of the most unsatisfactory of subjects in respect of the eccentricity of its nature and distribution in the fish class. Thus, no traces of an air-bladder are discernible in the lowest fishes—the lancelets and lampreys before alluded to. It is well represented in many common fishes, but certain of the latter—as, for example, the flounders and other flat-fishes—want it altogether, whilst the sharks, rays, and dog-fishes possess the merest rudiment of this organ. The special-creation theory affords no explanation of the anomaly of one fish possessing an air-bladder, whilst in certain of its near neighbours this structure is entirely absent. But the difficulty of the one theory of creation is, as we shall presently see, the triumph of the other. Even amongst ordinary fishes the air-bladder varies very much in form. In the cod and perch, for instance, the air-bladder is simply a closed sac or bag filled with gas. In the carp (Fig. 52), on the other hand, this organ (B, C) communicates with the throat (E) by means of a duct or tube (D); and in this fish, as well as in the roach, the air-bladder lies in curious relation to the internal ear, and probably serves some important function, such as that of increasing the resonance of sound. In the herring, the air-bladder appears to be placed in communication with the stomach; and in other fishes (*Corvina*, Fig. 53, *c*, and *Johnius*, Fig. 53, *b*) this structure is of complicated form, and is divided into a large number of ramifications and processes. It is interesting to note that whatever may be the nature

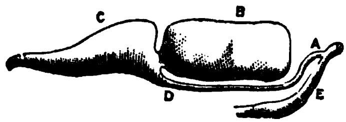


FIG. 52.—AIR-BLADDER OF CARP.

of the air-bladder in the adult fish, all air-bladders are provided with a duct in the young state. The duct becomes obliterated in such fishes as the cod and perch, leaving the air-bladder a closed sac, whilst it persists in the herring, carp, &c., as already noted. In all ordinary fishes the air-bladder has one settled function—it acts as a hydrostatic apparatus. By compressing or expanding this structure with its included gas, the fish is enabled to preserve a due relation between its own specific gravity and that of the water, and is thus enabled to rise or sink at will. It is interesting, moreover, to note, that so far as the history of both lungs and air-bladder can be constructed by the light of development, both structures appear to be modifications of one and the same primitive organ. The first use of both structures was probably that seen in the ordinary air-bladder to-day; namely, to form a receptacle for gas; this gas becoming used for breathing when the functions of the gills were interrupted. In this way, the functions of lungs were foreshadowed, and as the sequel will show, there is ample evidence at hand of such a modification having actually taken place.

But the story of the swim-bladder ends not thus. The mere knowledge of its functions and use in no wise aids us towards the understanding of what it is or of its origin. Yet we may trace this organ, from its form and nature in our common fishes, to the ancient ganoid group of fishes now sparsely represented in our seas by the sturgeons, by the bony pikes of North American lakes, by the Polypteri of the Nile and other African rivers, and by the still more curious Lepidosirens or mud-fishes (Fig. 54) of the Gambia and Amazon, and the Ceratodus or "Barramunda" (Fig. 50) of Australian fresh waters.

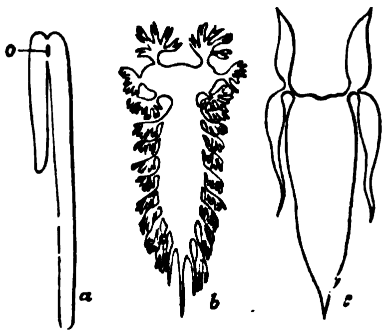


FIG. 53.—AIR-BLADDERS OF FISHES.

In the ganoid fishes, the air-bladder presents us with varying forms. In all, it communicates with the throat or stomach by a tube or duct, as in the familiar carp, which, however, is not a ganoid fish. It may be single or paired in the ganoid group, and we must note a more special feature of the swim-bladder of these fishes in that it frequently presents a cellular or divided structure internally. In the Polypteri of African rivers, the swimming-bladder (Fig. 53, *a*) is thus not only double, but divided internally into cells or small compartments; whilst it also opens into the throat by a distinct aperture (*o*). In the bony pike (*Lepidosteus*) it is quite as complicated in structure, and in the *Ceratodus* (Fig. 50) the air-bladder, whilst a single organ, exhibits a lung-like structure internally, and opens into the throat by a distinct opening or *glottis*. But in the mud-fishes or *Lepidosirens* (Fig. 54), which spend half the year amidst dry mud and the other half in their native waters, the air-bladder obtains its highest development. Here it is not merely double, but is also cellular internally, and communicates with the throat by means of a tube or duct. It is, moreover, provided at the extremity of this tube with an organ resembling the structure which guards the windpipe of higher animals. The nostrils, which in other fishes are simply closed pockets, open backwards in Lepidosiren into the throat, and thus place the air-bladder in communication with the atmosphere without. More noteworthy still, we find that part of the impure blood circulating through the body of the mud-fish is sent to this curious air-bladder, and circulates through its blood-vessels. From the air-bladder it is returned in a pure condition to the heart, and is thus fitted for re-circulation through the body. What is the meaning of this curious alteration in the function and use of the air-bladder? The answer is plain. The air-bladder in the mud-fish has attained its highest development. It appears as an organ receiving impure blood, which is purified in its cells. It receives air from the outer atmosphere for the purpose of purifying this blood. In one word, *the air-bladder of the fish has become a lung.*

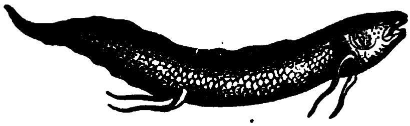


FIG. 54.—LEPIDOSIREN OR MUD-FISH.

Thus we discover that the air-bladder of the fish in reality represents the lungs of higher animals. Evolution would proceed still further, and ask us to recognise in the air-bladder the structures from which the lungs have been developed in the past—and a full consideration of the details just presented, strengthens this latter opinion. We noted that in the most primitive fishes (e.g. lancelet and lampreys) no swimming-bladder was represented. Its development therefore took place at a stage subsequent to the appearance of the ancestors of our existing lancelets and lampreys. Gradually, as the piscine type advanced, the air-bladder appeared. The forerunners of the sharks and their allies, which are as ancient as the ganoids, may have possessed an air-bladder, since we find rudiments of this organ in these latter fishes. But in free-swimming and surface-living fishes like the sharks and dog-fishes, or groundlings like the skates and rays, the necessity for a hydrostatic apparatus is obviated, as it is also obviated in the flat fishes which spend their lives on the sand. To the ganoids we must, therefore, look for the true history of the air-bladder. Equally ancient with the sharks and their allies, the ganoids, from their habits and ways of life, became provided with an air-bladder, which, as time passed, became still better specialised through the effects of use aided by "natural selection" as the propagating principles of a structure useful and advantageous to the race. As offshoots from a more ancient type of fishes, the first representatives of our common fishes probably developed an air bladder, which once again, owing probably to variations in habit, has become well developed in some (such as the carps, herrings, perch, and the like), but obliterated in others (such as the flounders and their neighbours), most probably from disuse.

The ganoid race has declined in numbers since the days of Devonian oceans, but its living members represent within their select circle the stages in the modification of the swim-bladder. In the sturgeons, the type of the organ is of primitive kind. In the Polypteri (Fig. 53, *a*) the air-bladder has become double; but in the

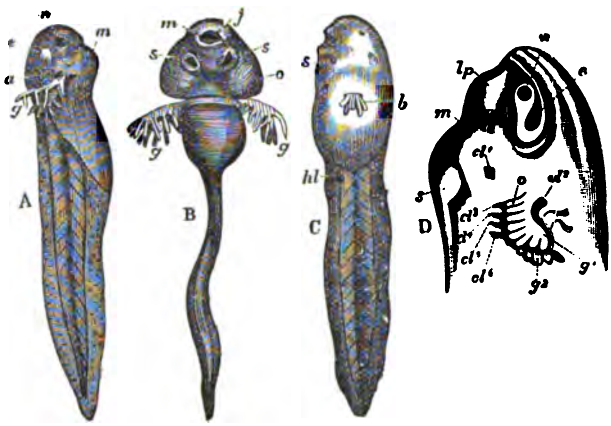


FIG. 55.—DEVELOPMENT OF FROG.
A, B, and C, Tadpoles; D, Head of Tadpole (magnified).

bony pike (*Lepidosteus*) it is not merely double, but exhibits a cellular or lung-like structure internally; and it is equally lung-like in Amia, another well-known type of ganoid fishes. Still more lung-like does the organ become in the *Ceratodus* or Barramunda (Fig. 50), where it is placed in relation with the blood-system. When, however, we reach the mud-fishes or *Lepidosirens* (Fig. 54), we pass the definite boundary which separates the swim-bladder from the lung, and discover an organ, not merely lung-like in structure, but which performs all the functions of a lung in purifying venous blood, and in returning such purified blood to the heart.

The lungs of the mud-fishes, formed thus by the gradual modification of an air-bladder, present us with the true origin of the breathing organs of all higher vertebrates. It is interesting to note that in the Climbing Perches and Ophiocephali—both characteristic Indian fishes—we find examples of fishes which appear actually to breathe air directly from the atmosphere, in addition to the air respired from the water by their gills. The former fishes appear to breathe out of water chiefly through a supply of moisture being retained in certain curiously twisted bones of the head. The latter fishes possess large cavities in the throat, air being admitted to these receptacles by the mouth. Impure blood circulating in the blood-vessels of these cavities is probably purified by the oxygen of the inhaled air, and the essential functions of a lung are thus discharged by the receptacles in question. Experiments on these fishes reveal the interesting fact that, unless they are occasionally permitted to gain free access to the atmosphere for the purpose of inhaling air, they die suffocated. The climbing perch, indeed, is known to make overland journeys, ambling along on its spiny fins in search of water, and presents thus a striking exception to the truth of the universally accepted apophthegm regarding the discomfort of "a fish out of water." We thus discover that the process of modification in the fish-class in the direction of air-breathing habits may be illustrated in other ways than by development of the swimming-bladder; although it must be borne in mind that the latter organ is the true representative and ancestor—as illustrated by Lepidosiren—of the lungs.

The lungs of true air-breathers, as seen in members of the frog class, may indeed (as in the *Proteus* and its neighbours) be actually inferior in structure to those of the mud-fishes. When we consider that, like the mud-fishes, the frogs and their neighbours breathe invariably by gills in early life (Fig. 55, *g*), in their tadpole stage, and afterwards, as represented by the frogs, discard their gills (*g*, *g*,) for lungs, we may discern in such a series of changes in the breathing apparatus the further stages through which the progenitors of the higher Vertebrata passed from the fish-like type and assumed that of the higher atmospheric breathers. For, as has been remarked by authority in matters biological, "the tadpole is at first a fish, and then a tailed amphibian, provided with both gills and lungs, before it becomes a frog, because the frog was the last term in a series of modifications whereby some ancient fish became a urodele (or tailed) amphibian; and the urodele amphibian became an anurous (or tail-less) frog. In fact, the development of the embryo is a recapitulation of the ancestral history of the species." Mr. Darwin, too, remarks that "morphology plainly tells us that our lungs consist of a modified swim-bladder which once served as a float;" and again: "According to this view, it may be inferred that all vertebrate animals with true lungs are descended by ordinary generation from an ancient and unknown prototype, which was furnished with a floating-apparatus or swim-bladder."

The discussion of biological odds and ends has thus brought us face to face with that great problem of nature—the origin of species—which admits of a fair and rational solution only on the hypothesis that change, alteration, and modification in living beings perpetuated by descent, and favoured or annulled by the action of "natural selection," constitute the factors which are responsible for the existing order of things. The most abstruse phenomena of nature and the most diverse facts of life, are brought by this theory into definite relationship, and made to serve as pathways towards the knowledge of still hidden laws. Under the old *régime*, in which the operation of a special creative force, alike erratic in its action and spasmodic in its work, was made to do duty as the originative method of this world and its belongings, the universe itself was simply a connection of paradoxes and insoluble enigmas. The naturalist of bygone days had need for a full cultivation of unreasoning faith in this unknown creative method; since of its apparent vagaries he was unable to give any rational account. Now, with the theory of evolution at hand, the disconnected facts of natural history fall into an harmonious and unbroken sequence of finger-posts and guides, pointing the way of creation as having passed through the pathways of descent, with modification as its henchman, and adaptation to new ways of life as its "guide, counsellor, and friend."

VII.

THE EVIDENCE FURNISHED BY THE SCIENCE OF LIKENESSES.

In the preceding chapter it was shown, incidentally to the subject of limbs and their nature, that science makes it a duty of the highest importance to discover and trace the resemblances which frequently exist between apparently diverse and unlike structures. Such likenesses were illustrated by a reference to the similarity which could readily be found to exist between such outwardly unlike organs as the arm of man, the wing of the bird, the fore-leg of the horse, the paddle of the whale or dolphin, and the wing of the bat. In a minor degree also, but still provable from the same standpoint, the paired fins of fishes could be shown to agree with the limbs of other animals to which they present no obvious affinities. Beneath the diverse appearances of limbs, one and the same type thus appears to exist. An examination of the hard parts, or skeletons, of these appendages, readily reveals the likeness which adaptation to diverse conditions of life has produced. In connection with the limb-likenesses in question, certain important considerations connected with the meaning of such similarities were briefly noted. How, or why, a common type or plan should be discernible beneath well-nigh endless variety of outward form and function, was a question which naturally obtruded itself upon the notice of the scientific observer. Such a query, it was remarked, presented, like so many other matters of scientific interest, but two methods of solution. In the one case the reply might take the form of the unquestioning and tacit assumption that such things were so formed from the beginning according to some ideal plan, or type—for the construction of which type, however, no reason can be assigned. "Conformity to a type" is an expression which merely restates what everybody admits, and what the examination of the limbs, on any hypothesis, plainly shows. To say that things "were created so" presents a complete parallel to the famous "woman's reason" in the "Two Gentlemen of Verona;" or to Tom Brown's equally renowned explanation of the dislike to Dr. Fell—a parody, by the way, on Martial—

> Non amo te, Sabidi, nec possum dicere quare;
> Hoc tantum possum dicere, non amo te.

Turning to the other side of the question, all that is mysterious and inexplicable on the special-creation hypothesis, becomes clear enough on that of "development" and "modification." By the idea of development is implied the derivation of the similar forms, or parts, from some common type, through natural laws of heritage and descent. By "modification," or "adaptation," we mean to indicate that potent power or factor, which, seizing the common type, moulds the structure—limb or body—to the special way of life in which the being ultimately comes to walk.

If the latter idea be correct or feasible, we can readily assign a reason why limbs, or any other series of structures in a given set of animals, should present such a close likeness. "Conformity to type" is no meaningless expression when used by the evolutionist. By his theory, he views this conformity as a proof of the blood-relationship—far or near, as the case may be—of the animals which exhibit the likeness in question. Such similarity is a proof of affinity, which can only be accounted for, in all its bearings, on the supposition that the beings exhibiting it are really kith and kin, but of varying degrees of relationship. It can readily be understood how important in the eyes of the modern naturalist this study of likenesses has become, since the facts it reveals largely assist him in constructing the true pedigree of the living world. There are many other considerations which serve to show the important nature of such a branch of inquiry—an importance equalled only by the interest which its pursuit is certain to evoke. When, for instance, it can be found that two organs so utterly unlike as the air-bladder of a fish and the lungs of a man are in reality closely connected in their nature, the information which the study of likenesses places at our disposal is seen to be of a kind which tends very materially to extend the knowledge that Bacon declared aided "the relief of man's estate." And the task of seeking and finding resemblances has had its due effect in solving not a few of the puzzles of biology. Only from the considerations it brings to view, and through the influence of the new way in which it compels us to regard forms and organs, has the mystery of such a subject as that of "rudimentary organs" been dispelled. The splint-bones of a horse, when examined by the light of this study, guide us, as we have seen, to the history of the equine race; and the transformations of animals and plants teem with new interest when investigated on the principles which the science of likenesses brings to view. It is to the details of such a subject that we now invite attention. Our illustrations will be culled from both worlds of life; and in our search after the likenesses whereon hangs the past-history of the living being, we may perchance light upon considerations not far removed from the wider questions that border the origin of man himself.

The "science of likenesses" is known to specialists as "Homology," and it may further our ready appreciation of the details to be presently treated in these pages if we make mention likewise of the term "analogy" and its meaning. The latter word is, as a rule, very loosely used in ordinary life. Scientifically employed, its meaning is clear enough. In a dictionary we find it explained as meaning "correspondence, or likenesses in some ways, proportions, or effects." Obviously, the term is used in a general sense to mean any degree of likeness, resemblance, or relationship between objects. In science, the word "analogy" has but one distinct meaning. It implies identity or correspondence in *function* or *use*, and nothing more. When two things are used for the same purpose they are "analogous;" and no further resemblances or likenesses are required in science to justify the use of the term. Every one knows that a bird's wing is a very different structure from that of a fly or butterfly. The one is really a fore-limb; the other being merely an expansion of the skin of the body. But despite their wide difference in structure, they are truly "analogous," being used for one and the same purpose, that of flight. In this sense alone, can any two objects be truly termed "analogous."

Now, turning to "homology," we discover a deeper relationship between organs and parts than that indicated by analogy. That two things may be truly named "homologous" it is not necessary to think of their use in any sense. The all-important consideration on which the science of likenesses hangs, is the fact of identity or correspondence in *fundamental structure* or in *origin*. Such a correspondence is illustrated by the subject of limbs already referred to. The arm of man, the fore-leg of a horse, and the wing of a bird, are used each for a different purpose. They are not "analogous," but they are undoubtedly "homologous," because, beneath the diversity of form and function, we can readily perceive the striking similarity of fundamental structure or type. Thus things may not be what they seem, when viewed by homology—for the wings of bird and butterfly, alike in the popular sense, are utterly unlike; and regarded in the same light many things are what they do not seem. The seeming unlikenesses of arm, wing, and fore-leg are thus merely superficial, and serve to hide the deeper realities that link them firmly together as the same in type, and presumably the same in origin. It may happen, lastly, that two organs may be both analogous and homologous. But the presence of both degrees of likenesses is at the best accidental, or induced by like conditions of life which do not affect the deeper considerations which homology brings before us. The wing of the bird and that of the bat are formed each from a fore-limb—although in diverse ways—and each subserves the purpose of flight. Analogy and homology seem to run in parallel lines in this instance. But the conditions in virtue of which a quadruped like the bat has acquired its powers of flight may have been, and probably were, different in nature, as they certainly were in time, from those under which the bird learned to soar in the air. This latter point, however, is foreign to the main issue before us. Sufficient for our present purpose are the thoughts, that homology and analogy are two distinct things; that homology indicates the deeper and real likeness between organs and parts; and that these two forms of likeness are not necessarily connected or coexistent.

So much by way of introduction to the subject of the science of likenesses. It requires but little guidance to enable the mind to follow up the line of thought already mentioned in the preceding remarks, which shows the function of this branch of inquiry in detecting the hidden relationships and bonds which connect one living being with another, or one class of organisms with a neighbouring class. Such relationships, as every one knows, are indicated by the systems of classification and arrangement which form an important part of every science, and, one may add, of many matters connected with every-day existence as well. Thus, the classification of the objects under his study or care is equally important for botanist and librarian; and in either case the aim of the system of arrangement is to bring together things that are like, and to separate those that are unlike. It matters not how this procedure is effected. Classifications vary with well-nigh each person who undertakes their formation; and the needless multiplication of systems of arrangement, equally with the persistent invention of new cognomens for already well-named species, constitute the two chief sorrows of the well-regulated scientific mind. The best classification is of course the "natural;" but it so happens that this particular arrangement is not always easy of construction: a fact chiefly explicable on the ground that the natural relationships of living beings are often hard to seek and difficult to find. When the popular classification of the fish with the whale—one, it may be added, not characteristic of primitive minds alone—is replaced by the union of the whale with the quadrupeds—seeing that it has warm blood, brings forth its young alive, and nourishes them by means of milk—a grossly artificial system of arrangement is superseded by a true and natural one. That a whale need not be a fish because it swims, or is fish-like, is thus evident; and the correctness of our arrangement of whales and fishes, and of the whole animal and plant worlds, must of necessity depend on the completeness of our knowledge of the objects we intend to classify.

Now, it is exactly the difficulties which stand in the way of forming a natural arrangement of animals and plants which are lightened by the study of homology as the science of likenesses. From the mere arrangement and classification of living beings, it may be readily seen how we advance through the study of scientific resemblances to questions of deeper import, connected, in these latter days, with the problem of the very beginnings and origin of all living things. Before the days of evolution—at least, as represented in its typical phases of modern times—speculative philosophy was hard at work, trying to discover the "archetype" underlying the familiar types and varied plans of animal and plant structure. Goethe and Oken, for instance, by the most remarkable of coincidences, ventilated an idea concerning the ideal plan of the skull, which had been independently suggested to each philosopher by a casual glance at the bleached skull of a sheep in the one case and of a deer in the other. This idea was expressed in the theory worked out with patience and care amongst ourselves by Professor Owen, and known as the "vertebral theory of the skull." Briefly stated, it was held that the skull in reality consisted of modified *vertebræ* (or joints of the backbone); and that, so far from being a something different from the other parts of the skeleton, the skull was really modelled on the type of the spine. Owen recognised four such vertebræ in the skull; and it need hardly be remarked that the views of Owen, as expressions of philosophical anatomy, were far in advance of those of Oken and Goethe, the former of whom went so far in the matter of speculation pure and simple as to assert that in the skull the whole body was represented in miniature. The head, according to Oken, was a kind of *multum in parvo* of the bodily structures. Therein his subjective philosophy actually found fingers and toes in the shape of the teeth. But the history of zoology includes the recital of a hot and strong controversy over the ideas emanating from Oken and Goethe, and emended and improved by Owen. Soon Owen's views were denied and combated, amongst others by Huxley, in 1858, who held them to be disproved by the study of the skull's development. The skull from its earliest phases was maintained to exhibit a very marked difference from the spine: and if two structures thus differed in their earliest phases, and when their type should have been most apparent, how, it was asked, could their identity be insisted upon? A long and elaborate series of researches has, since the time we speak of, been undertaken with reference to the homology of the skull. And with what result, it may be asked, to the idea of real likeness or unlikeness between skull and spine? The answer to this question would vary with the scientific predilections of the person who replied. But it is not too much to assert that the impetus which was first given to the search after a likeness has been increased by the light which evolution and the science of likenesses have together thrown on the reason why not merely skull and spine should resemble each other, but why likenesses and differences—due to multifarious and varying conditions of life and development—should also exist between these structures.

The old view of Goethe in its general acceptation may be held to be strengthened by later research. The recent view of Owen has been modified in some quarters to the effect that no less than twenty segments or vertebræ compose the skulls of higher animals. But the fundamental conception of the newer view seeks to recognise in the vertebræ of the skull, not so much an exact correspondence with the fully developed vertebra as with the primitive type of the latter structure. Professor W. K. Parker, whose labours in this field are so well known, for example, declares that there exists "no definite evidence of segmentation in the history of the highly perfected" gristle-skull of such a primitive and ancient stock of fishes as the sharks, dog-fishes, and rays; and he further remarks, that "we do not conceive of the skull as being composed of a number of coalesced vertebræ; not having perceived any indications of any process of coalescence in the embryo, and being unaware of any evidence of the past occurrence of such a transformation in ancient times." It need not be added that the likeness of the skull "segments" of modern anatomists to the complicated "vertebræ" of which the earlier workers conceived the skull to be composed, is by no means included as a part of the views of later research. The "segments" of the skull, in other words, are not necessarily the elaborate "vertebræ" we now behold in the spine. Indeed, Professor Parker is very exact in insisting upon the fact that in fishes and amphibians—by which latter name we designate the frogs and their relations—there is but one well-defined bony segment to be descried. "And," adds this author, "in these forms there are no good grounds for assigning to the cranial bones special names indicating a correspondence to particular parts of vertebræ." In the skull of quadrupeds there are but three well-defined segments, according to Professor Parker; but it does not follow that they constitute three cranial (or skull) "vertebræ"; and very decisive are his succeeding words: "We cannot admit that our investigations give any reason for describing the skull as constructed by the modification of a series of vertebræ, still less for viewing it as directly made up of a number of cranial vertebræ." But our author does not leave us in doubt as to the difference which his views entail between former ideas of the composition of the skull and the results of recent research. "We find," says Mr. Parker, "that every form of skull that has been investigated, every stage in development, contributes to one idea, which becomes simpler, more intelligible, more harmonious, by the pursuit of a right process of investigation. There is a unity of structure in the skeleton of the head, a fundamental formal unity, which may always be perceived; and an adaptability to the most varied conditions of life in water, on land, in air, which becomes more, and not less, astonishing as knowledge slowly and surely increases."

Thus the correctness of the theory that the skull is formed of modified vertebræ in reality depends on the special standpoint from which we regard the name "vertebra." Viewed as to its *development*, and compared with the development of vertebræ, the segments which every anatomist recognises in the skull assuredly present no resemblance to the joints of the backbone. But if we enlarge the definition of a vertebra to include the idea of a segment of the skeleton forming the axis of the body and protecting the nervous and blood centres, then the segments of the skull may correspond to such description. Here, however, we construct a definition of the vertebra, without reference to its development; the latter source of information being the most trustworthy in reference to the nature of the things and belongings of life. As Huxley has remarked concerning skull and spine, "though they are identical in general plan of construction, the two begin to diverge as soon as the one puts on the special character of a skull, and the other that of a vertebral column; the skull is no more a modified vertebral column than the vertebral column is a modified skull." This view exactly accords with the requirements of the theory of evolution, which would impress that, in the course of descent from the primitive spinal and skulless stage of organisation, the skull has been specialised from the general vertebrate type, just as the vertebræ themselves have risen from their first rude outlines to their present and modified condition.

Thus have grown the ideas which the casual study of a broken sheep's skull first generated; and thus do we find an illustration of the method in which a study of homology leads us towards an understanding of the true nature of an organ or part in living beings. But for this science of likeness—but for the results of long, careful, and laborious research into the comparisons which may be legitimately drawn between the formation of the skull in one animal and in another—the answer to the question "What is a skull?" might have been left in the position of a riddle propounded by the Sphinx itself. Thus much has resulted from the study of likenesses—namely, a clear gain of much knowledge concerning the true nature of an intricate portion of the animal frame. It yet remains to be shown how the progress of evolution has helped and aided the true understanding of the modifications which the skull has undergone in its progress from the unspecialised type of primitive vertebrate life; and, conversely, how the existence of such modifications aids, confirms, and supports the basis on which the development theory may be said to rest. Says Professor Parker, "We are necessarily led to see that this unity of structure, this relationship, includes extinct creatures as well as those now living. And the student cannot but seek for some further light than is involved in the establishment of the fact that there is a unity in the structure of all vertebrate skeletons. An explanation is required; we want to comprehend how this unity in diversity has come about. Morphology (the science of structure), studied in the history of embryos, reveals to us an evolution by which the skull passes through one grade of structure after another, becoming advanced and changed by almost imperceptible gradations until the adult type is attained, in a certain number of days and weeks. This evolution is continually going on within our experience; and we little think of its marvels. And yet many find it inconceivable that the same process of evolution can have taken place in past ages, so as to produce from small beginnings the varied fauna of the globe. The natural forces which in a few days," concludes Mr. Parker, "make a chick out of a little protoplasm and a few teaspoonfuls of yolk, are pronounced incompetent to give rise to a slowly changing, gradually developing series of creatures, under changed conditions of life. Yet to our minds the one is as great a marvel as the other; in fact, both are but the different phases of one history of organic creation."

The old idea of the "archetype" is thus seen to become resolved into, and to be replaced in time, and through the progress of scientific research, by the primitive form from which all the varied structures of the same kind have arisen by a natural process of evolution. The science of likeness and the theory of development mutually support and confirm each other. No longer do we search for an "archetype" skull or for a typical vertebra. The creative idea in this or in any other department of natural science is not contained in some perfectly formed structure, with all its complexities and intricacies of form already apparent. The true object of our search is for the primitive type; and the way of our seeking lies through the modifications and paths by which, from that simple type, the abstruse and the complex have been evolved.

The present is perhaps the most appropriate stage of our inquiries at which to point out that, whilst the broad features of likeness in a series of animals or plants—such as those exemplified by the limbs of higher animals—are only susceptible of explanation on the theory of evolution, or, in other words, "of inheritance from a common ancestor," there are other features which demand a somewhat different method of treatment. When the subject of homologies is regarded in a broader aspect, we become aware that it is not only possible, but necessary, to regard likenesses from two points of view. The broad homologies of limbs are to be explained, as just remarked, by the theory of descent from a common ancestor. Such structures, the direct product of blood-relationship, are to be called "homogenous," and illustrate the purest examples of the "likenesses" we are discussing. But it has been already remarked that a law of "adaptation" forms, along with descent, a factor of no slight importance in modifying the structures of living beings. Every living thing is subject to the perpetual and continuous action of its environments or surroundings. Such outward influences may favour or retard the evolution and growth of new parts and organs, and will unquestionably induce now, as in the past, alterations in the structure and form of the living being. Of the exact influence and extent of the external causes of variation we know very little, but of the existence of such causes no one entertains a doubt. The question, however, presents itself as to the nature of the likenesses and differences which such outside influences may produce. All likenesses or homologies which cannot be accounted for on the theory of descent from a common ancestor are named "homoplastic," according to Mr. Ray Lankester's terminology. As an example of both kinds of likeness, it may suffice to cite the limbs and heart of higher vertebrata and the swimming-bladder of fishes, as illustrative of "homogenous" parts, or those which are the products of inheritance. The heart of a bird and a quadruped are "homogenous" organs, but the cavities or compartments are "homoplastic," or, in other words, have been developed independently of each other, as, in all probability, have the feathers of the one and the hairs of the other. It is well, therefore, to take into account this false or incomplete "likeness," which expresses no blood-relationship, and which, in its production, involves much that is obscure. We can explain the likeness between limbs on the theory of descent from a common type; the likeness between a worm and a lobster, in respect of their jointed bodies, becomes clear on this theory; but we cannot so account for the close likeness between the individual joints of a worm, or between those of a lobster, or, for that, between the feelers, jaws, and feet of the latter animal, on the principle of inheritance. Mr. Darwin says: the formation of such structures "may be attributed in part to distinct organisms, or to distinct parts of the same organism, having varied in an analogous manner; and in part to similar modifications having been preserved for the same general purpose or function."

Leaving, as still under the shadow of unapprehended causes, the variation of parts from outward forces operating upon the living being and its structure, let us turn to some clear examples of plain, though at first sight unapparent, "likenesses," which may be drawn from both animal and plant kingdoms. Our examples may comprise a wide range of subjects; but this facility of illustration is in itself a proof of the universal application of the science of likeness to explain the modifications of common types through which the forms of life have come to exhibit that diversity which is at once the wonder and the charm of living nature.

No better starting-point can well be found than within the region of flowers and fruits, whereof many familiar objects may be shown to teem with the lessons of highest philosophy. Once again, Goethe's name comes to the front as the chief originator and expounder of those likenesses between very diverse organs, the true import of which relationship the great poet-philosopher himself did not fully comprehend. In his work "Versuch die Metamorphosen der Pflanzen zu erklären," bearing date 1790, Goethe, following hard upon Caspar Friedrich Wolff, enunciated his thoughts concerning the "Metamorphoses" of plants. It is necessary first of all to clearly understand the significance of this phrase "metamorphosis," and its applications to the study of likenesses. With Goethe, the phrase implied what we now term "abnormal development." It meant the chronicle of the changes which might take place in the usual plan or type in which a plant was built up. The production of a "double flower" was to Goethe, as it is to us to-day, an example of metamorphosis—of the alteration of parts from their normal type. What may be said, however, to be the bearing of these discoveries on the elucidations of the problems of animal and plant forms and existence? The reply is clear to us to-day, although to the believer in "freaks of Nature" the question would have been impossible of solution. To the latter, a monstrous development, or a departure from the ordinary type of things, was an evidence that Nature was given occasionally to play strange pranks without reason or meaning. The very phrase "sports" of Nature, applied to the monstrosities or abnormalities thus produced, indicates with sufficient clearness the opinion respecting the frivolity of Madre Natura which the old naturalists entertained. A double flower and a "Two-Headed Nightingale" were equally good illustrations of the "freaks" in which Nature was wont to indulge. The idea that possibly the production of a monstrosity in animals and plants was as directly due to the operation of law as the birth of natural progeny was never entertained, until the genius of Goethe and his successors pointed out that in the so-called abnormalities of life we might find a clue to the primitive forms of living things. In the production of her "freaks" Nature was "showing her hand," so to speak, and lifting a corner of the veil in which her ways of development were so thickly enshrouded. The transformations and metamorphoses of animals and plants, viewed in this light, are but the occasional return of Nature to primitive ways and methods of working. On the idea that living things have not always existed as they now appear, we behold in deviations from the normal type a clue to the stages and states of long ago. On the theory that creation has been from the first a stable and unaltering collection of living forms, the metamorphoses and variations of animals and plants are simply grounds for the exhibition of wonderment and vain surprise.

Amongst the most important of the generalisations which Goethe deduced from his study of the variations of plant structure and life, was that which held that "the leaf is the type of the whole plant." Not merely can it be shown that every appendage of the stem is a leaf of one kind or another, but it may also be proved that the plant itself arises from a seed which is in its essential nature merely a peculiarly modified bud. Strange indeed is it to think that between the gorgeous beauty of the blossom, or the complex nature of the flower and its parts, and the simple leaf, there should exist such close and intimate connection. But the likenesses or homologies which underlie the varied forms of plants may be readily illustrated by a brief reference to familiar facts of flower structure. Flower buds spring from the protective base of leaves called *bracts*. Now, these leaves exhibit every transition and gradation, from the ordinary leaf of the plant to the more characteristic leaf we see protecting the flower bud. Next in order, the botanist asks us to note that bracts themselves may insensibly pass by easy ways and gradual stages to correspond with the outer parts of the flower. There are four parts in a

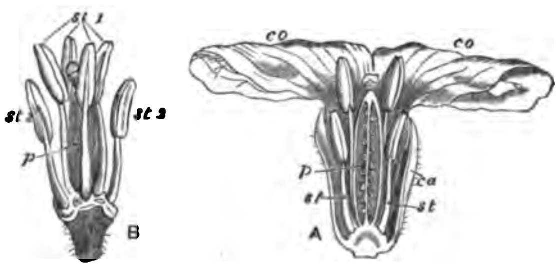


FIG. 56.—WALLFLOWER.

perfect flower (Fig. 56), arranged as circles or whorls of leaves placed in an alternating fashion as to the individual leaves, one whorl within the other. Beginning at the outside of the flower, we find the *calyx* (*ca*), composed, as a rule, of green leaves called *sepals*. Next comes the brightly coloured part—without which, in popular acceptation, a "flower" would not merit the name—the *corolla* (*co*), composed of leaves called petals, which alternate with the sepals. These two outer whorls are the *floral envelopes*. Within the corolla, we find the *stamens* (*st*), each consisting of a stalk and a head, in which latter is developed the yellow dust called *pollen*, by which the "ovules" are fertilised and converted into the fertile "seeds." Last of all, and in the centre of the flower, the *pistil* (*p*) is to be noted. This part consists of one or more *carpels*, in each of which we note a lower part called the *ovary*, wherein the ovules (which become the *seeds* after fertilisation with the pollen) are contained. Thus much by way of a brief lesson in elementary botany. Now, when we study the bracts, we find that insensibly these have a tendency in many flowers to become like the green sepals of the calyx. Look at a *Camellia* in bud. You will see the numerous bracts, and also the five sepals, and you will further gain a good idea from this familiar example of the absolute identity which may exist between bracts and sepals. In the "Hundred-leaved Rose" you will find illustrated, in an equally plain and perfect manner, the likeness of sepals to the green leaves of the rose plants; and in the geranium the same phenomenon is occasionally seen. From the green calyx with its sepals, to the coloured corolla with its petals the transition is just as readily made. In *Camellia Japonica* we behold such an interesting and gradual transition from sepals to petals. In some plants (e.g. Indian Cress and Fuchsia) the calyx,

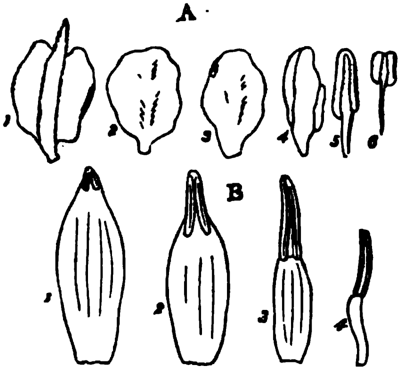


FIG. 57.—STAMENS CHANGING TO PETALS.

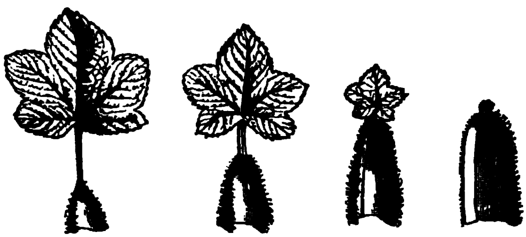


FIG. 58.—GOOSEBERRY LEAVES BECOMING SCALES.

instead of being green, may be coloured; this fact indicating a transition from calyx to corolla in one way. On the other side, we find the petals may be developed as ordinary leaves, and thus we learn that petals, like sepals, are simply modified leaves.

The case for the apparent substantiation of Goethe's maxim grows stronger when we approach stamens (Fig. 56, *st*) and pistil (*p*). If the stamen be in reality a leaf, it is also certain that it resembles a leaf much less closely than the sepal or the petal. The stamen is a stalked organ, as we have seen, and bears in its head or "anther," the yellow *pollen*. This head seems to represent the folded blade of the staminal leaf, but have we any proof that our conjecture is probable or correct? Let the facts of botany reply. Here is a *Petunia*, for instance, in which the stamens are replaced by stalked leaves; and here a leaf (Fig. 58) degrading to become a mere scale. There a white Water Lily (Fig. 57, B) and a Double-rose (Fig. 57, A), in both of which cases we may observe the transition stage whereby the stamen (4, 6) becomes a petal; whilst the petal in the rose may become in its turn a sepal (Fig. 57, A, 1). So, too, in the common tulip, the three parts of the pistil and the six stamens may all be transformed into petals. Nor does the central organ of all, the seed-producing pistil, escape these metamorphic changes. The double-flowering Cherry (Fig. 59) shows its carpel in the shape of a green leaf (*b*). The willow flowers show us gradations from the leaf-like carpel to the altered stamen, and thence to the ordinary leaf; and we may, lastly, find in some plants, as in the monstrous specimens of Dutch Clover, that every part of the flower becomes a leaf. Goethe's own words regarding the pistil succinctly express the true state of matters regarding its abnormal history: "If we keep in view the observations which have now been made, we shall not fail to recognise the leaf in all seed-vessels, notwithstanding their manifold forms, their variable structure, and different combinations." Thus Goethe's generalisation finds its best proof in the facts of vegetable monstrosities. And the science of likenesses, tracing nature in her bypaths of development, discovers that, whatever may be said of the first beginnings of plant life on the globe, the later development which has given us the flowering plants has apparently been directed wholly, or in greater part, towards the elaboration of the leaf. To the evolution of the leaf, as the science of likeness proves, we owe the wondrous beauty of the flowers, which, like the stars of the poet, brighten earth's otherwise dull firmament.

FIG. 59.—DOUBLE-FLOWERING CHERRY.

It is both interesting and important to note that some botanists hold the view that the original organs of the flower consisted simply of stamens and pistil, these organs being alone necessary for the production of seeds. The petals are to be viewed as "flags," serving to attract insects for fertilisation, as will hereafter be explained. The petals are thus regarded as modified stamens, and yellow is considered to be the original colour of flowers. Unquestionably, the most simple and least modified flowers are yellow, and we know that stamens are extremely apt to develop into petals, or, at least, into leaf-like structures. But such considerations do not affect the general axiom of Goethe that the leaf is the type of the whole plant; for before stamens and pistils were developed at all, there must have existed leaf-like organs adapted for nourishment, and, as we see in lower plants, exercising reproductive functions as well. Stamens and petals, in other words, are secondary developments; the leaf remains, as before, the type of the whole plant-kingdom.

The flower, however, is not the only part of the plant which has received abundant elucidation at the hands of the science of likenesses. The ingenuity of Nature and the prolific nature of the expedients by which she has developed structures to serve her varied ends, formed of old two of the stereotyped sources of wonder by the recital of which philosophers were wont to regale their auditors. This fertility of device in using simple means to effect important ends receives a new reading from the study of homology. We now perceive that the modifications effected by nature represent the utilisation of like parts in divers ways. Just as essentially similar limbs may be employed in the animal world for very different purposes, so the variations of similar parts in plants may illustrate what is meant by "homoplastic" organs—that is, the adaptation to new and varied ways of life, of the common belongings of the plant world. Our comprehension of this truth may be firstly assisted by an example culled from the animal world. The idea that Nature, "in framing her strange fellows," and in developing the unusual and unwonted, should effect her purpose by the creation of new structures and fresh parts, is an idea for which there apparently exists the warrant of common sense. But let us see if the way of Nature in such a case is not rather by the elaboration and modification of already existing parts. Take as an illustrative case the Tortoise (Fig. 60) and its structure. No single animal form stands apparently more aloof from its neighbours of the reptile class than the sluggish chelonian. Enclosed in a bony box, its structure seems to be unique, and its relations to the serpent, lizard, or crocodile extremely unapparent. But what has comparative anatomy to say respecting the building of the chelonian house? Look at the roof formed by the greatly expanded ribs and solid spine. Regard its sides formed by the cartilages or ends of the ribs; and its floor formed by certain skin-bones comparable roughly in their nature to the large scales of the crocodile's under surface, and in any case presenting us with no structures unusual or

FIG. 60.—TORTOISE.

foreign to the reptile class. The boxlike body of the animal is, in short, formed by so much of its skeleton, and by so many of its scales, altered and modified to suit the animal's way of life. It presents us, thus, with no new thing in the way of structure, but with an elaboration of the common elements of the reptile body.

More interesting, perhaps, because more complex in their relations, are the changes which occur in the lower jaw and ear, as we ascend from the fishes as the lowest vertebrates to Man and quadrupeds as the highest. We could not find a better example of the manner in which Nature moulds the same elements into widely different forms than the latter subject. Homology teaches us clearly enough that in the elaboration of the skull, as in the modification of the tortoise-skeleton as a whole, new parts and new organs are evolved simply and for the most part by the alteration and higher development of the original type. When we examine the lower jaw and its connections with the skull in any vertebrate animal below the rank of the quadruped, we find that the jaw is attached to the skull by the intervention of a special bone called the "quadrate bone." The manner in which lower jaw and skull are connected in Man and quadrupeds is very different from the latter arrangement. In Man, as every one knows, the lower jaw works upon the skull directly and of itself, and the "quadrate bone," which one sees so distinctly in the reptile, bird, frog, or fish, is apparently wanting in higher vertebrate life. Is the skull of the quadruped, then, modelled, as regards its lower jaw and articulations thereof, on a different type from that seen in the lower vertebrate? Comparative anatomy supplies the answer in a highly interesting fashion.

Attend for a moment to the disposition of the parts of the internal ear, which in quadrupeds we find to exist within the skull and just above the lower jaw. We find three small bones (Fig. 61, A, *m*, *i*, *c*,) to connect the "drum" of the ear with the internal hearing apparatus. Of these three bones, one shaped somewhat like a hammer is named the *malleus* (*m*), and to this

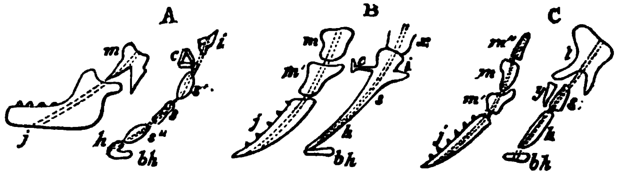
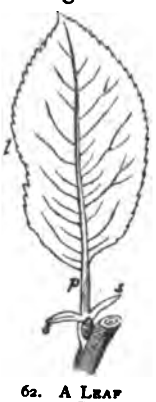


FIG. 61.—JAWS OF VERTEBRATA. A, Quadruped; B, Lizard; C, Fish.

bone our attention must be specially directed. For when we trace this bone downwards through the reptiles and birds towards the fishes, we discover that it alters its relations to the ear and assumes new ones with the lower jaw. In reptiles and birds, for example, we find the malleus to be of large size, and to be divided so that one part (B, *m*) becomes transformed into the "quadrate bone," and another (B, m^1) into the upper part of the lower jaw (*j*) itself. In the fish a third bone (C, *m''*) may actually appear in connection with the lower jaw (*j*), and as the result of the division of the part representing the "malleus" of Man and quadrupeds. So that, divesting the subject of all technicality, we may say that, as we first enter the vertebrate sub-kingdom, we find the "malleus" to be represented in the fishes by no less than three bones (C, *m*, *m'*, *m''*) which are connected with the upper part of the lower jaw and lie outside the ear altogether. Next, in the reptile and bird we find a modification of this arrangement to hold good. Here the malleus is divided into two portions (*m*, m^1) only; these parts, however, being still concerned in the articulation of the lower jaw (*j*). But in Man and his neighbour-quadrupeds (A), these outside bones become pushed upwards in the course of development, and are finally enclosed within the skull. They thus appear as the "malleus" of the ear (A, *m*), having no connection with the jaw, and being concerned in the higher function of conveying impressions of sound to the internal ear. The upper part of the lower jaw of the lower vertebrate is in fact taken into the interior of the skull and ear, when we reach the quadruped class. The two companion bones (A, *c*, *i*) of the malleus in the ear, likewise represent separate parts of the skull, which in higher life become modified for the hearing function. And a glance at the accompanying diagram will serve to show how the other bones—"incus" (*i*) and "stapes" (*c*)—of the quadruped ear are represented wholly or in part in lower life, and how they attain their higher place and function simply as the result of modification, and of the evolution of a new structure from the materials of an already existing type. Such modification is simply part of the wider process we see everywhere illustrated in animal life at large, whereby complication and diversity of structure and form are the results of no new creations, but of the development, the splitting up, and differentiation of already existing parts.



62. A LEAF AND ITS PARTS.

So is it also, with plants in some of their most unusual aspects. The strange features in animals and plants are in reality but the altered "commonplace of nature." By way of illustration, the subject of the threadlike "tendrils" of plants presents itself in a prominent manner. It would be hard to discover any organs of plants which are better known than these. Poetic allegory itself has ever found in the simile of the "tendrils," the best guise under which the affections of mankind might be shadowed forth; and that weakstemmed plants climb by the aid of these organs, is not a matter requiring even a primer of botany for its verification. Now, plants of very varied nature possess these organs; and the question arises, are these tendrils new and special organs in such plants as possess them, or are they but modifications, like the home of the Tortoise, of familiar structures? Let the science of likenesses reply, by directing our attention to the general form of the leaf. Every ordinary leaf (Fig. 62) consists, as we know, of a stalk or *petiole* (*p*) and a blade or *lamina* (*l*), and when we look at the apple leaf (Fig. 62), or at a rose leaf, we may see at the point where the leaf-stalk leaves the stem, two little wing-like appendages, called *stipules* (*s s*), and which are probably to be regarded as normal parts and appendages of the leaf. These stipules are large in the pansy tribe, and are also prominent in the beans and peas, whilst in one of the vetches (Fig. 66)—*Lathyrus aphaca*, the Yellow Vetch—the stipules, as we shall see, may actually represent the leaves. In many other plants, on the contrary, no stipules occur.

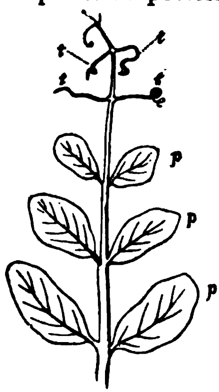


FIG. 63.—LEAF OF PEA.

Now let us examine the leaf of the Common Pea (Fig. 63). It is a compound leaf, and we notice that the tendrils seem to grow out at the sides and at the end of the leaf-stalk. The tendrils (*t t*) here, are at once seen to exist in the place of some of the leaflets (*p*), and are formed by the end of the leaf-stalk also. We find a very simple modification to be thus represented; certain parts of a leaf, in other words, become altered to enable the plant to climb. Tendrils here are "homologous" with leaflets and leaf-stalk. In the lentil, it is the leaf-stalk itself which is long drawn out to form the climbing thread. The vine (Fig. 64) or passion-flower may be selected as our next example. Here the tendrils appear to be formed in a very different fashion from that seen in the pea. Apparently the tendril (*t t*) in the vine and passion-flower is a modified branch; such an opinion being arrived at from a study of the relations of the tendril to the stem and normal branches of the plant. The Virginia Creeper likewise climbs by means of its altered tendril-like branches. Once again we meet with a similar

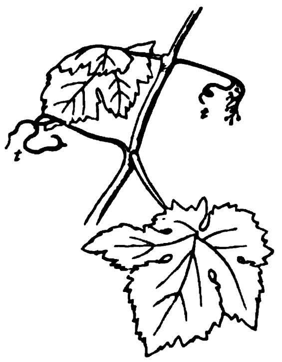


FIG. 64.—TENDRILS OF A VINE.

end—that of forming a climbing support—served by a different means, when we turn to the Smilax (Fig. 65), which in Southern Europe replaces the Bryony of our English hedgerows. The leaves of Smilax are heart-shaped, and when we look at the points at which the leaves spring from the stem, we detect two tendrils (*t t*), which pass to the surrounding plants there to entwine themselves in complex fashion. Now, what are the tendrils of Smilax? Our knowledge of the leaf and our observation of the position of our tendrils enable us to answer the question. What organs arise from the base of the leaf-stalk? The reply, illustrated by a reference to Fig. 62, is "stipules" (*s s*); and stipules are paired organs. Therefore, we conclude that the tendrils of Smilax are simply altered stipules. The Yellow Vetch (Fig. 66), which adorns our cornfields, reverses the conditions of Smilax. The stipules (*s s*) remain in the Vetch to represent the leaves, whilst the leaf-stalk itself and its leaflets become altered as in the Pea, to form tendrils (*t t*) and to enable Lathyrus to indulge its climbing propensities. Thus does a study of tendrils illustrate in apt fashion the bearings of homology. But for this science of likenesses we should not be enabled to unravel some of the complexities which beset the study of how a plant climbs; and we again note how modification and adaptation, as distinguished from new creations, form the way of the world of life.

FIG. 65. LEAVES OF SMILAX.

FIG. 66.—YELLOW VETCH.

No less interesting in certain of its aspects is the study of the "thorns" and "prickles" which "set the rose-bud," or give to the hawthorn its characteristic name and feature. The popular botany of every-day life is content to consider prickles and thorns to represent one and the same kind of structure. But the science of likenesses is careful to ask us to make a very decided distinction between their nature as between the tendrils themselves. Examine the Sloe (Fig. 67, A), for instance, or the Hawthorn, and you will readily determine the nature of the "thorns" which these plants bear. You will note that from the thorns (*a a*) leaves spring, and in this observation lies the key to the understanding of their relationship with other parts of the plant. Leaves are only borne on the stem itself or on the appendages of the stem we familiarly call branches. Therefore the presence of leaves on the thorns, plainly tells us that these appendages of Sloe and Hawthorn are in reality stunted branches. Nor are we left in the slightest doubt as to the nature of these objects; for many of the plants which in a wild state possess thorns alone produce full-grown branches under cultivation. "Spinosæ arbores cultura sæpius deponunt spinas in hortis," said Linnæus, and the Sloe itself illustrates the remark. But the prickles of the Rose (Fig. 67, B), which might readily be deemed thorns in miniature, now demand attention. The prickle has no intimate connection with the stem. On the contrary, it is merely a hardened appendage of the skin of the stem or leaf as the case may be. A prickle causes no trouble in its detachment from the stem, and the botanist would inform us that these appendages in their true nature correspond to hardened hairs. Lastly, we may meet with double prickles, or spines, which spring from the axils of leaves and from the base of the leaf-stalk. In the Acacias and the American Prickly Ash (*Echinopanax*) we may see spines the origin of which is not hard to trace, and which spring from the bases of the leaves. Just as the tendrils of the Smilax were formed from "stipules," so we perceive in the Acacias how these latter organs may be altered to form the "spines," or "prickles," of these plants.

FIG. 67.—SLOE AND ROSE, WITH THORNS AND PRICKLES.

Passing from leaves and flowers to fruits, we enter a new but equally interesting field of speculation with the last. Let us firstly inquire what is the nature of the structure to which the botanist gives the name of "fruit." It is perfectly evident from the common knowledge of Nature's processes which ordinary observation affords that the fruit is merely part of the flower. The buds of springtime and the blossoms of summer must precede the fruit of the autumn; and the promise of "a golden reaping" is heralded by the early growth of the vernal season. Without the flower, then, the fruit would be non-existent, and considering that within the vast majority of fruits we find the seeds, we can readily construct a definition of the botanical fruit by defining it as "the ripe pistil." Such is the invariable nature of the fruit in the mind of the botanist. Popularly, however, "fruits" are only to be so called when they are edible. The mental and scientific concept of the man of science vanishes before the practical matter-of-fact definition of a fruit as that which is good to eat; and perhaps each definition meets in its own way the exigencies and circumstances which called it forth.

But the study of fruits from the botanical side, presents us with a highly interesting illustration of the value of "homology," as showing us how the modification of simple and well-known parts of the flower may become transformed so as to be well-nigh unrecognisable in the fruit. No better illustration of the latter fact can be found than in the Strawberries (Fig. 68), which secured the full admiration of Dr. Boteler, who declared that "Doubtless God could have made a better berry, but doubtless God never did"—a remark the correctness of which will probably be viewed proportionately by the individual minds and tastes which may consider the saying. Glancing at the Strawberry flower, we see no promise therein of the toothsome fruit which the summer brings; and we may well be puzzled to discover the true nature of our berry, even after a close examination of its substance. The apple cut across is seen to contain seeds—therefore we may reasonably enough imagine that, whatever growth has produced the fleshy fruit from the apple blossom, we find the seed-producing pistil of the flower to be represented in its interior. But no seeds are to be found in the interior of Dr. Boteler's berry. Where, then, is the true fruit—the ripened pistil—of the Strawberry, and what is the nature of the succulent mass we eat? The science of likenesses answers the question by a reference to the growth of the Strawberry itself. In the flower, the pistil is seen to be composed of a great many little parts, called "carpels"—equally well seen in the pistil of a buttercup. As the flower fades and the pistil ripens, the end of the flower-stalk (called in botany the *receptacle*) begins to swell out and to exceed the rest of the flower in its growth. Soon it becomes red and succulent, and the little green carpels of the pistil, each containing a single seed, come in due time to be separated from each other, and to be embedded in the juicy mass on which, when it was the simple end of the flower-stalk, it was set. Thus to offer a friend the "botanical fruit" of the Strawberry would be a proceeding tantamount to invite him to a Barmecide's feast: since, to fulfil the promise, we should simply require to pick out from the surface of the berry the little green carpels (*f*) which represent the ripe pistil of the flower—the popular "fruit," as we have seen, being merely the enlarged end of the flower-stalk. In such a case, one might well be excused for preferring the common construction of the term "fruit" to the scientific, and for neglecting the intellectual aspect of the berry in favour of the exercise of practical æsthetics as applied to the end of the flower-stalk.

FIG. 68.—STRAWBERRY.

The Strawberry does not stand alone in its illustration of the curious facts concerning the transformation of flowers which the study of homologies elicits. What, for example, is to be said of the Rose-fruit (Fig. 69) itself, save that the familiar red "hip" of our hedgerows is formed by the enlarged and hollowed flower-stalk (*c*), along with the calyx (*s*) or outer and green part of the flower; or, according to some botanists, by the calyx alone, whose green leaves become thickened, red, and glistening as the summer passes into the autumn, and come to enclose the true fruit (*fr*) in the form of the little "carpels" similar in nature to those on the outside of the Strawberry. So that the difference, in one botanical theory at least, between the "hip" of the Rose and the Strawberry, simply consists in the fact that the Rose flower-stalk is hollow and has the fruits inside, whilst the end of the Strawberry flower-stalk is solid, and has its fruits outside. The Apple and Pear likewise exhibit much the same arrangement as the Rose and Strawberry in respect of their fruits. If we suppose the hip of the Rose to have its walls extremely thickened and fleshy, we should convert it into a form of fruit resembling the Apple or Pear. No less interesting is the nature of the Fig, which, to be properly understood, should be examined as it grows in the hothouse. Slice your fig longwise (Fig. 70 *a*), and you will see in its interior, not seeds, but "flowers"; some with stamens (*b*) alone, others (*c*) with pistils alone. The Fig appears before us as another example of the hollowing of the flower-stalk, with this important difference, that not merely the fruits but the flowers are contained in its interior.

FIG. 69.—ROSE FRUIT.

It only remains for us to sum up the results and general conclusions to which our brief study of the science of likenesses may be said legitimately to lead us. Turning firstly to the features we have just been discussing, we have noted, for instance, that the leaf was the type of the whole plant, and that as the leaf became modified to form the "flower," so that flower and its parts, still representing leaves, became further altered to form the "fruit" under all its varied aspects and forms. From a simple structure—the leaf—we thus discover, by the aid of the science of likenesses, complex and elaborate organs and parts to be developed. What lessons do such examples teach us concerning the order of Nature at large? Do these lessons argue in favour of evolution or against that theory of Nature? The answer is not for a single moment doubtful. If, as our inquiry shows, it is the way of Nature to produce many and varied structures by the modification of one simple organ or part, surely there is no greater wonder involved in the idea, that by the same process of development she has woven from simple forms, the

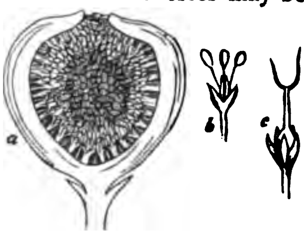


FIG. 70.—SECTION OF FIG.

whole complex warp and woof of the living world. When we see Nature in her abnormal methods of development revealing to us, under the guise of her sports and freaks amidst the flowers, the true composition of the pistil and stamens, or altering the same structure to form the varied fruits; when we discover that the complex skull has apparently been built up through slow and gradual modifications from skulls of simpler type, which vanish away, in the lowest confines of the vertebrate animals, and disappear in the barely defined skulless "cord" of the lowest fish, we may not esteem it an impossibility that all organic forms have been evolved under like conditions of development.

Nor must we omit to think of another important point involved in the study of homologies. If Nature is, as we have shown, liable to modify and alter continually the work of her hands, can such a practice be held to favour the origin of new species by the way which evolution points out? When the flower returns to the leaf-type, or when it exhibits variations from its usual form and structure, is Nature going back or reverting to former conditions? or is she initiating paths which lead to new species? The answer to both of these queries may be given in the affirmative. When the flower grows into its leaves, that is a "reversion," a stepping backward to the primitive and simple type. When, on the other hand, the plant shows a tendency towards complexity, instead of simplicity—to alter in favour of increased development—then is seen the tendency to progression and elaboration of the type. Both tendencies hold sway in Nature, and the one is as inexplicable as the other, save on the theory of Evolution. From the monstrosity of the flower a new "variety" springs, and in time the variety becomes a "race," and the race in turn a new "species." Thus, whilst the course of Nature before our eyes runs not smoothly but in an apparent irregularity, the deeper faith in a law-governed universe, not as yet fully comprehended or known, convinces us that with the higher knowledge of to-morrow, the irregularities of to-day will resolve themselves into parts of an ordered system. It is not without good reason for believing in the reality of the convictions which nature-studies inspire respecting the government of this world's order, that we find Professor Parker maintaining that "the study of animal morphology leads to continually grander and more reverential views of creation and of a Creator. Each fresh advance shows us further fields for conquest, and at the same time deepens the conviction, that, while results and secondary operations may be discoverable by human intelligence, 'no man can find out the work that God maketh from the beginning to the end.' We live as in a twilight of knowledge, charged with revelations of order and beauty; we steadfastly look for a perfect light which shall reveal perfect order and beauty."

VIII.

THE EVIDENCE FROM MISSING LINKS.

When the Darwinian theory of the origin of living species and other theories of evolution were yet in their infancy, the subject-matters of the present paper had attained notoriety, if not fame. The early critics of the hypotheses of evolution were not slow to fix upon "missing links" and their nature, their assumed absence, and the impossibility of supplying them, as weapons of satisfactory kind and lasting strength, against such ideas of the order in which the living universe had been formed. Especially has the phrase found favour in the eyes of critics of an unscientific cast of mind—those "old ladies of both sexes," to use Huxley's words, who consider the "Origin of Species" "a decidedly dangerous book," and who regard most contributions to the literature of evolution as works of darkness in the most literal sense of the term. Persons who would have been puzzled had they been asked to mention a single example of a case where "missing links" were required, nevertheless were found ready with much unction to declare that Mr. Darwin could never be expected to fill the gaps in question; and the argument as against evolution, in the early days of which we are speaking, was frequently supposed to be clenched with the triumphant query, "Where are the missing links?" A feature of Darwinism and evolution, not to speak of natural history at large, so apparently familiar as the subject before us, deserves some detailed examination. It is not too much to say, that even with the lapse of years, and with the better understanding by cultured persons at large of evolution, its weaknesses and its strength, the nature of "missing links" is often imperfectly understood. Apart from the necessity for some clear understanding of what is demanded by the opponents of evolution, and of what evolutionists and naturalists are able to present in reply to these demands, the present topic may be said to have grown in importance with the most recent discoveries in geological science. Its true nature, and its attitude to the existing phases of evolution, are therefore matters for careful inquiry; since their investigation may powerfully aid the solution of the great problem which evolution endeavours in one phase to solve—the how and why of living Nature and her ways.

The widespread recognition, even in the popular mind, of the importance of the discovery of "missing links" between existing species of animals, in so far as the welfare of evolution-theories is concerned, is not difficult to trace or account for. Taking for granted the very reasonable and obvious admission that any theory of evolution must rest upon the idea of the production of new species by the modification of the old, it follows that in our examination of living nature we should expect to find evidence of the connection between the varied forms of life in existence. From the monad up to man, the evolutionist postulates an unbroken series—not, indeed, as many suppose, in one straight undeviating line, but rather after the idea of a great tree with countless branches, offshoots, and diverging twigs, which, however, unite in their lower limits in a common stem. Now, is it possible, when we look around at the varied forms of animal and plant life, to trace this unbroken sequence, this continuity of structure, and this connected relationship? The common observation of nature, not to speak of even an elementary acquaintance with popular zoology, forbids the idea, and at once negatives the supposition. The forms of life, animals and plants, fall into groups and divisions of varying extent and different rank in the scale of creation. In each large group we include a number of lesser divisions, the members of which are united by certain common characters. But even in the smallest of our classes or orders, the gaps betwixt the included forms are many and wide; and Nature, as we observe her processes, does not appear to supply the "missing links," in the existing order of affairs at least. In that great sub-kingdom of the animal world which zoologists have parcelled out as the *Vertebrata*,—or the territory wherein man and quadrupeds reign as the aristocrats, birds and reptiles as the middle classes with their varied estates and ranks, and frogs, toads, and fishes as the lower orders and substrata of vertebrate society,—the gaps existing between the various classes are very patent and clear to the merest tyro in natural history. Not even the proverbial old lady with a marked partiality to a belief in the marvellous in natural history, or towards a literal interpretation of the compound zoological character of certain wondrous beasts mentioned in ancient fables, could be brought to entertain seriously the idea of the existence of an animal half-reptile, half-bird. Still less easy is it for the popular mind to conceive the existence of a creature midway as to structure between the bird and the quadruped. Whilst certain small jokers—a race happily becoming, as regards scientific matters, well-nigh extinct—might be perfectly safe in challenging zoologists at large to produce the "missing links" between man and his nearest animal relations; or to show on Lord Monboddo's hypothesis, the various stages in the decline of man's caudal appendage, upon the disappearance of which that witty *savant* is presumed to have founded a large part of man's physical and moral supremacy. Amongst lower forms of life the gaps are equally apparent, and the continued distinctness of each species would seem to argue powerfully at once in favour of the "special creation" of the varied kinds of animals and plants, and against the evolution of new species from the old, and against the hereditary connection of species one with another. The argument derived from the visible gaps between even nearly related kinds of animals, was therefore too apparent to be overlooked by popular critics of evolution, and it was also too important to be made light of by evolutionists themselves. "Distinct now, distinct always," was the opinion which was duly expressed regarding the nature of species, in the early days of the historical controversy concerning their origin. We may not be surprised, therefore, to find Mr. Darwin, in speaking of this subject, saying that one objection to his theory, "namely, the distinctness of specific forms, and their not being blended together by innumerable transitional links, is a very obvious difficulty;" and again, "Why is not all nature in confusion, instead of the species being, as we see them, well defined?" Alike grave, then, to evolutionists and their opponents is the question of "missing links." Let us endeavour to examine this question in the light of recent research, with the view of determining to which side the balance of evidence, duly weighed, will lead us.

Amongst the procedures commonly witnessed in our courts of law there is one which I believe is styled, in legal parlance, "taking an objection to the relevancy of the record or indictment." The essential feature of that procedure consists in one of the interested parties showing that certain parts of the statement of facts made by the opposing side involve items which may be absolutely untrue or incorrect, and which therefore require to be expunged from the list of matters involving litigation. In this way the details of a lawsuit become simplified, and the chariot-wheels of justice are enabled to roll easily onwards in that glorious ease and uncertainty of movement which is one of the most ancient if also unsatisfactory characteristics of legal science and practice. The contention before us at present in one respect admits of its issues being amended through an objection to their relevancy. The chief points for discussion are those concerning the need for "missing links" according to the theory of evolution, and the ability or inability of the evolutionist to supply them. Let us suppose, however, that counsel for the evolutionist moves the relevancy of these points. The following will be his line of argument :—"It is demanded that we produce the 'missing links,' or transitional forms between existing species. Unquestionably the demand is a just one ; and in furnishing its reply, it is clear we must point out such links either in the existing world, or in the fossils found in rock-formations, as representing the life-systems of the past. We shall be able presently to demonstrate that whatever evidence geology has to show is all in our favour, and that where a want of evidence exists, such deficiency is no fault of ours, but depends on the 'imperfection of the geological record.' But there exists an equally important consideration for our opponents, in the fact that the very circumstances under which new species are produced may frequently *obviate the necessity for the existence of missing links and transitional forms.* This latter contention can be supported by the plainest evidence, and on this preliminary point—namely, the reason for the justifiable and natural absence of transitional forms—we may firstly lead evidence."

Is it necessary, then, that we should, by the laws of, and in the very nature of the origin of species by, evolution, or by Mr. Darwin's principle of "natural selection," always expect to find transitional forms connecting existing species? Mr. Darwin's reply to this question is a negative. The new varieties or species which appear will tend, by the very conditions of evolution, to present improvements on the species which preceded them; and, on the principle that "the weakest go to the wall," the ancestors of existing species will in many cases have become exterminated by their successors being better adapted than themselves to survive in the "struggle for existence." The parent-species will fail in the competition involved in the struggle with its offspring. Viewing each species as usually the product of an improved constitution, we may naturally expect the parent-form and the transitional links to have become exterminated, as Mr. Darwin remarks, "by the very process of the formation and perfection of the new form." But extinct animals are liable to be preserved as "fossils" in the rocks composing the crust of the earth, and yet "missing links" are not discoverable in any adequate proportions. This latter fact has already been mentioned, and the reason assigned in the fragmentary condition of nature's great geological museum. Neglecting the geological evidence for the nonce, it might still be contended that living species as noted by us to-day should be more closely connected than they are, were their creation by evolution and descent a probable theory.

Now, the pith of the evolutionist's reply consists in showing that such connecting species or forms are by no means to be expected as a matter of course, and that their absence is, in fact, actually favourable to his views and opinions. Consider a well-known and proved case of the origin of very different varieties from a common stock, that of the Pigeons. The various breeds or races of pigeons, of which the four best known are the pouters, fantails, carriers, and tumblers, may be certainly regarded as having descended from the Rock Pigeon (*Columba livia*). Between the various breeds of pigeons, the differences are so marked as to be of "specific" character. Their variations are so plain and distinct, that had these birds been met with in a wild state and been examined by ornithologists, they would have been assuredly classified as distinct "species," and not as mere "varieties" of one species—so apparent are the differences in size, in colour, in feather-arrangement, and even in the skeleton. Such an instance stands, therefore, as a most typical case of the origin of new races or of new species by the modification of the old; and its consideration will show us the futility of the demand that the original stock should resemble the descendants to which it has given origin. There exists no necessity that the rock pigeon should be intermediate between any two of the four breeds just mentioned, or that any two of these races—say the fantails and pouters—should in turn evince combinations of the characters of each other.

Mr. Darwin remarks of the pigeons and their history, that "if we could collect all the pigeons which have ever lived, from before the time of the Romans to the present day, we should be able to group them in several lines, diverging from the parent rock pigeon. Each line would consist of almost insensible steps, occasionally broken by some slightly greater variation or sport, and each would culminate in one of our present highly modified forms. Of the many former connecting links, some would be found to have become absolutely extinct, without having left any issue; whilst others, though extinct, would be seen to be the progenitors of the existing races. I have heard it remarked as a strange circumstance," he continues, "that we occasionally hear of the local or complete extinction of domestic races, whilst we hear nothing of their origin. How, it has been asked, can these losses be compensated, and more than compensated?—for we know that with almost all domesticated animals the races have largely increased in number since the time of the Romans. But on the view here given we can understand this apparent contradiction. The extinction of a race within historical times is an event likely to be noticed; but its gradual and scarcely sensible modification, through unconscious selection, and its subsequent divergence, either in the same, or more commonly in distant, countries into two or more strains, and their gradual conversion into sub-breeds, and these into well-marked breeds, are events which would rarely be noticed. The death of a tree that has attained gigantic dimensions is recorded; the slow growth of smaller trees and their increase in number excite no attention."

The true view of the matter really consists in our recognising that the likeness and relation of new species or races to their parent stock depend on the circumstances of human observation, and on the exact lines along which the variation has proceeded. Occasionally each likeness is apparent; at other times, by the very manner of development of the new species, it is non-existent. Nor must we forget one all-important consideration, which, according to Professor Huxley, Mr. Darwin himself somewhat overlooked. It is a frequent fact, hereafter to be noted, that, despite the Linnæan aphorism *Natura non facit saltum*, Nature may and sometimes does take not merely a jump, but a running leap from one species to another. What would be thought of the history of the Ancon or Otter sheep, which about the close of last century was born of an ordinary ewe as the progeny of an equally commonplace male parent; both, along with fourteen other ewes, having been the property of a certain Seth Wright, a Massachusetts farmer? This Ancon sheep differed most materially from its parents and from the ovine race at large, in possessing a large body and proportionally short legs. For sundry reasons, connected with the over-lively habits of his long-legged sheep in leaping over their fences, Wright from this one Ancon sheep, in due time, bred a whole flock of pure Otter sheep; the breed being allowed to die out on the introduction of the Merino sheep. Presuming that, in ignorance of its true and sudden origin, the history of the Ancon breed had been made the subject of biological speculation, how would the demand for "missing links," and the evolutionist's inability to reply to the demand, have been construed? Simply as against the transmutation of the sheep species or race, and as against the origin of the Ancon by the variation and modification of the ordinary sheep. And yet the Ancon race had certainly its beginning in the sudden modification of an existing race such as utterly precluded the possibility of any "connecting links" having been developed or required.

Such considerations, we may submit, will tend to weaken the relevancy of the demand for "missing links" and transitional forms. But it may be worth our while to hear a little further testimony on the same point. Taking Mr. Darwin's own examples, we find him citing the instance of a journey from north to south, over a great continent, in the course of which we meet with closely related or representative species, which represent each other in their respective regions or habitats. Such species are found to meet and interlock, and thereafter, as our journey proceeds, one species is found to become less frequent, until it is completely replaced by the other. Even in the common or middle region where these two species intermingle, the members of the one group are as absolutely distinct from the other, as if specimens had been selected for comparison from the headquarters of each species. Yet, says Mr. Darwin, "by my theory, these altered species are descended from a common parent;" each in the process of descent having exterminated the parent species and also the transitional forms. Once again—leaving the extinct and fossil species out of consideration for the present—the question crops up, why do the species not intermingle in the middle region, with intermediate conditions of life? Here geology steps in to reconcile the discrepancy. Because your continent is continuous from north to south to-day, it is not lawful to infer that this continuity of land-surface always existed. Changes of land, and the separation of even our great continents into detached portions of territory, are not theories, but facts of geology. And, admitting the existence of separate islands or disconnected portions of land-surface, the distinction of species by such separation, and the absence of intermediate forms, would be fully accounted for. Nor must it be lost sight of that the neutral territory or "No Man's Land" common to two species, is usually small and ill-defined as compared with the wider territory or area of the distribution of each group. And again, the range and extension of a species, and its power of commingling with other species, will be materially affected by the range of distribution of other and already well-defined groups. The species will be preyed upon by these latter groups, and the tendency to mix and unite with its nearest allies is thus lessened and limited; whilst the fact has been already noted that the narrow and limited character of the common area is by no means favourable to a blending of the characters of the nearly related groups. Conversely, in a larger area, with less risk of destructive competition from other species, we find the representative group attaining the maximum of its development, and, even in point of greater numbers alone, attaining a marked and characteristic personality, as do the representative species alluded to in the north and south of a large land-surface. Each species thus "fighting for its own hand," and either aided, or on the other hand weakened, by surrounding conditions, improves or decays, without mixing with neighbouring groups.

Summing up these preliminary observations on the theory that "missing links" are by no means so necessary on a fair showing of Nature's ways and polity as might be supposed, we may submit, firstly, that the favourable variation of a species is a slow process, depending not merely on changes in the constitution of the included animals or plants, but on many other external causes, such as changes of climate, and the like. Secondly, in connection with this first discouragement to the mixing of specific characters, we must remember that detachment of land-surfaces will account for the absence of intermediate forms; and in cases where such forms have existed, they would be developed, as we have seen, in fewer numbers than the species they would tend to connect; lesser numbers implying few chances of either actual or geological preservation.

But we may not forget that up to the present stage we have been merely contending for the relevancy of the indictment. Supposing our objections to the invariable necessity for "missing links" have been maintained, there yet remain very many instances wherein, as the evolutionist would freely admit, such connections require to be supplied, theoretically or actually, for the support of his case. The connected chain of life which the evolutionist postulates, implies the presence of numerous links; the chief question relating to the exact stages or points at which these links are demanded—and this question again depending on another, "What is or was the exact sequence and order of development?" Suppose Mr. Browning to be as correct in his poetic rendering of the "Descent of Man" as he is—judged by ordinary theories of evolution—absolutely incorrect, when he says in "Prince Hohenstiel Schwangau"—

> That mass man sprang from was a jelly lump
> Once on a time; he kept an after course
> Through fish and insect, reptile, bird, and beast,
> Till he attained to be an ape at last,
> Or last but one,—

then, according to the poet's rendering of man's evolution, his descent would imply connecting links between the amœboid or protoplasm stage of his existence and the "after course," and also between the successive stages of which that "after course" is alleged to consist. Fortunately for scientific criticism, poetry possesses an invaluable commodity known as "licence;" and it may suffice in the present instance to remark that the sequence and succession of life indicated by the most psychological of modern poets, are certainly not those held by Mr. Darwin, or by any other competent biologist. Man's descent from the gorilla—the chief element in the evolutionist's creed as propounded by popular notions and by a dogmatic but unlearned theology—is, after all, but "the baseless fabric" of a vision, from which a better acquaintance with the facts of nature, and with theories explanatory of these facts, will most effectually awaken the unconvinced. The knowledge of what evolution really teaches and reasonably demands constitutes, therefore, the first condition for ascertaining what "missing links" are required. To bridge over the gulf between the gorilla or any other anthropoid ape and the human type, may be the mental bane and lifelong worry of unscientific minds contorting the demands of evolution—such a task is certainly no business or labour of Mr. Darwin and his followers, or of any other school of evolution. And Mr. Darwin, writing in his "Descent of Man," and after a review of man's theoretical origin, is careful to add, "But we must not fall into the error of supposing that the early progenitor of the whole Simian (or ape-like) stock, including man, was identical with, or even closely resembled, any existing ape or monkey." We must, in truth, look backwards along the "files of time" to the point whence, from a common origin, the human and ape branches diverged each towards its own peculiar line of growth and development on the great tree of life.

Thus much by way of caution in alleging how or what "missing links" are to be supplied. The contention that, even on the showing of the evolutionist, the connecting links between distinct groups of living beings are not supplied even to the extent he himself requires, is answered in the expression of Mr. Darwin already quoted, namely, "the imperfection of the geological record." No fact of geology is more patent than that, to use Sir Charles Lyell's words, "it is not part of the plan of Nature to write everywhere, and at all times, her autobiographical memoirs. On the contrary," continues this late distinguished scientist, "her annals are local and exceptional from the first, and portions of them are afterwards ground into mud, sand, and pebbles, to furnish materials for new strata." The very process of rock-formation consists in the rearrangement of the particles of previously formed materials, and the manufacture of new strata implies the destruction of the old with the included "fossils" of the latter. The geological series is thus certainly a detached and discontinuous collection of formations, interrupted by gaps of considerable and often undeterminable extent. Of the contemporaneous life-history of the globe, during the periods of time represented by such gaps, we have no record whatever. But even when the materials for forming a detailed history of any past period of our globe are found in tolerable plenty, the record is never complete. "We can never hope," says Lyell in a most emphatic passage on breaks in the sequence of rock formations, "to compile a consecutive history by gathering together monuments which were originally detached and scattered over the globe. For, as the species of organic beings contemporaneously inhabiting remote regions are distinct, the fossils of the first of several periods which may be preserved in any one country, as in America, for example, will have no connection with those of a second period found in India, and will, therefore, no more enable us to trace the signs of a gradual change in the living creation, than a fragment of Chinese history will fill up a blank in the political annals of Europe." Add to these considerations the brief chronicle of a long and important chapter of geological history, namely, that soft-bodied animals and plants are rarely preserved as fossils; that land animals are but sparsely represented in any formations as compared with marine forms; and that even "metamorphism," or the alteration of rocks subsequent to their formation, is known to alter and obliterate their fossil contents,—and we find reasons of the most stable and satisfactory kind for the imperfect nature of even the fullest records of rocks and of their fossils that man has been able to obtain.

But in what direction does the positive evidence we have been able to obtain lead? Clearly to the side of evolution, and towards the supply of "missing links" in a fashion which even the most sanguine expectations of scientific ardour could scarcely have hoped to see realised. Bearing in mind that vast tracts of rock-formations are as yet absolutely unexplored, the present subject is seen to be one to which each year brings its quota of new and strange revelations. And at the most, any one record of what has been done towards supplying "missing links" must be held to be merely provisional, and to serve but as a prelude to the discoveries of a succeeding period. Especially within the last few years, however, has the evidence of the existence of animals which may fairly be deemed "missing links" accumulated in a very marked degree, and in some cases in a very astonishing fashion. The reader has but to become informed of recent discoveries amidst the Tertiary rocks of North America, to learn the surprising revelations concerning intermediate forms between existing groups of mammals or quadrupeds, which, chiefly through the researches of Professor Marsh, have been added to the conquests of science. What, for example, is to be said of the zoological position of the huge *Dinoceras* (Fig. 71) and its allies, creatures as large as existing elephants, and which, from the examination of their skeletal remains, can at the best be regarded as intermediate betwixt the elephants themselves, and the odd-toed Ungulates (or hoofed quadrupeds), such as the rhinoceroses, &c.? Dinoceras thus possessed two large canine teeth (*c c*), six small molars (*m*) on each side, and four horn-cores (h^1 h^2), besides a pair of similar structures in front of the upper jaw. Or, again, which rank, save that of an intermediate position, and as a veritable group of "missing links," can be assigned to the extinct quadrupeds, included by Marsh under the collective name *Tillodontia*, the remains of which occur in the Eocene Tertiaries of the United States? For how else should we classify animals with great front teeth like the *Rodents* or "gnawers," grinders like the *Ungulates* or hoofed quadrupeds, and a skull and skeleton generally like that of the carnivorous Bears? Or, once more, what can be said of the affinities or relationship of the extinct *Toxodonts*, also from American deposits, in which the characters of Rodents are united to those of Ungulates and Edentates—the latter being a group of animals represented by the existing sloths, armadillos, and ant-eaters? Nor is the list of extinct quadrupeds which fall into no existing group, but present a union of the characters of several distinct divisions, exhausted with the foregoing brief chronicle. Again drawing upon the well-nigh inexhaustible treasure-house of geological specimens in the recent deposits of the New World, we find the extinct *Marauchenia* connecting the odd-toed hoofed mammals

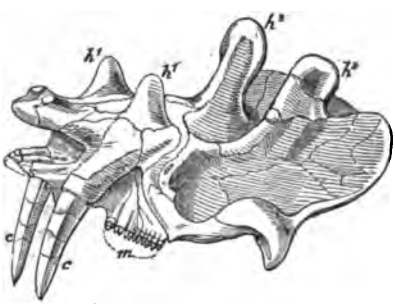


FIG. 71.—SKULL OF DINOCERAS.

with the even-toed division. Passing to the whales and their kin, we find the extinct *Zeuglodon* with its well-developed teeth—a feature unusual in living whales—appearing to connect the whale tribe with the seals and their allies. Similarly, the curious *Anoplotherium* (Fig. 73) of the Eocene Tertiary deposits appears to connect the swine race with the true cud-chewers or Ruminants, just as the *Palæotherium* (Fig. 72) itself—one of the first animals whose remains were disinterred from Montmartre—connects the pigs and tapirs with the apparently far-removed rhinoceros. The case for the existence of "missing links," wherewith the at present distinct orders and sub-orders of quadrupeds may be connected, would thus seem to be very strong. There would appear to be more than sufficient cause to account for the hopeful spirit of the evolutionist, whose scientific prophecy, that philosophic research into the nature of fossil organisms—begun by Cuvier, in the now classical quarries of Montmartre—is destined to powerfully aid his cause, seems likely to be realised. When it lies in the power of the naturalist to point, as well he may, with pride, to the perfect series of forms and missing links which connect the one-toed horse of to-day with the curious three, four, and five-toed steeds of the past, one may overlook the jubilant tone of the evolutionist in the more silent and deeper satisfaction with which mankind at large is given to welcome the demonstration of a great truth. It is of such a demonstration that Huxley writes: "On the evidence of palæontology, the evolution of many existing forms of animal life from their predecessors is no longer an hypothesis, but an historical fact; it is only," he adds, "the nature of the physiological factors to which that evolution is due which is still open to discussion."

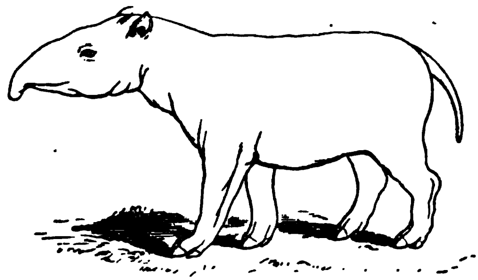


FIG. 72.—PALÆOTHERIUM (RESTORED).

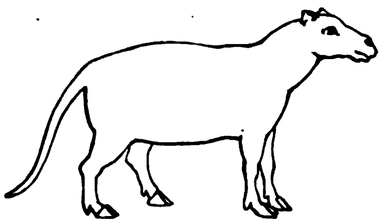


FIG. 73.—RESTORATION OF ANOPLOTHERIUM.

But not merely in the highest class of the animal world have "intermediate forms" been discovered. The case for evolution grows in interest when we learn that in lower ranks of Vertebrate life, groups of animals, separated apparently by the widest of intervals, are now being linked together by the discovery of intermediate fossil forms. The best-known example of the latter facts is found in the relationship which may be now regarded as being clearly proved to exist between reptiles and birds. Were we to search the whole animal kingdom through for examples of creatures of thoroughly different appearance, habits, and general conformation, no two groups would fall more familiarly to hand than birds and reptiles. There would, indeed, appear to be no similarity or likeness between the secretary bird, which daily devours its quota of snakes, and the prey upon which it lives; or, reversing the comparison, betwixt the unfortunate bird and the serpent whose stony gaze has allured it literally to a living death. Activity of organisation on the one hand would be opposed by a torpidity of action on the other; beauty of form and colour, by appearances frequently grotesque, and often, in popular estimation at least, repulsive. The contrast is one which, in the popular view, would be complete and perfect in every respect. Birds are warm-blooded, and have a four-chambered heart: reptiles possess a slow circulation, a low blood-temperature, and a three-chambered heart, which, however, in the crocodiles becomes four-chambered. The former class is covered with feathers, the latter with scales, bony plates, or both. The fore-limbs, modified for flight in the bird, are never thus used in reptiles—the so-called "flying lizards" (Fig. 74) possessing no true powers of flight, but being enabled by a parachute-like arrangement of their front ribs to take flying leaps from tree to tree. Birds, as we well know, want teeth; and although in tortoises and turtles, as typical enough reptiles, a dental apparatus is also wanting, the reptilian character tends decidedly towards a large and perfect display of teeth.

FIG. 74.—FLYING DRAGON.

A closer inspection and comparison of the skeletons of the two groups, such as may be made in a very general review of their bony possessions, would reveal several interesting points of likeness and also of divergence. Thus both classes have a lower jaw which may be called "compound;" since, unlike the simple two-halved lower jaw of quadrupeds, that of birds and reptiles is composed of numerous pieces united to form the single bone. Then, also, this lower jaw is joined to the skull, not of itself and directly, as in man and quadrupeds, but by a special bone named the *quadrate*, which, curiously enough, by a wonderful process of alteration and metamorphosis, becomes represented in man and quadrupeds by one (the *malleus*) of the small bones of the ear (see page 135). Such, among others, are a few points of agreement between reptiles and birds.

But plain grounds of distinction are apparent within the same region of "dry bones." A bird has never more than three fingers (thumb [*g*], and two next digits [*d*, *e*, *f*]) in its "hand" or wing (Fig. 75); and the supporting bones of these fingers, corresponding to our "palm," are united together. The reptile's fingers are never so few as three, and their palm-bones, moreover, are not ossified together. The "merrythought" of the bird (Fig. 76, *j j*), indissolubly associated with mystic forebodings of hymeneal nature, consists of the two united "collar-bones;" such a disposition of the collar-bones being unknown in the more prosaic reptilians; and the great "keel" (*f*) seen on the bird's breast-bone (*g*) is wanting on that of living reptiles. Next in order, we find that the *sacrum*, or bone wedged in between the haunch-bones, consists, in birds, of a goodly number of vertebræ or joints of the spine, whereas, in the reptile, one or two vertebræ form the *sacrum*. In all birds, save the ostrich tribe, the two haunch-bones (Fig. 76, *p*, *r*) are not united below or in front in the middle line. In reptiles such a union does take place, this union, indeed, being also seen in man and quadrupeds. In birds, the tail terminates in a "ploughshare-bone" (Fig. 76, *d*), giving support to the oil gland, the secretion of which is used in preening the feathers. In reptiles no such bone exists, and the joints of the tail simply taper towards the extremity of the appendage. The axis of the thigh-bone (*t*) in the bird, like that of quadrupeds, lies parallel with the median plane or axis of the body; but in reptiles, the axis of the thigh makes an open angle of varying dimensions with the median plane.

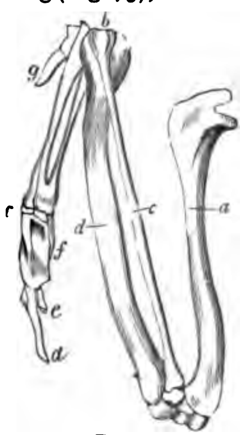


FIG. 75.
SKELETON OF BIRD'S WING.

The ankle of the bird (Fig. 77) is peculiarly formed, inasmuch as the upper half of the ankle, or "tarsus" (*a*), becomes united to the lower end of the shin-bone or leg (*t*); whilst the lower half of the ankle unites with the bones corresponding to those of man's instep, the union producing the so-called "tarso-metatarsal" bone (Fig. 76, *w*). It is this bone which becomes so greatly elongated in the waders, such as the storks and ibises. As seen in the young fowl (Fig. 77B), the shin or leg-bone (*t*) bears at its lower extremity the "astragalus" (*a*) of the ankle, shortly to be firmly united to the leg by bony union (A). The latter condition is seen in the left-hand figure (A), where the astragalus (*a*) has become united to the tibia, or chief leg-bone (*t*); the other bone of the leg, or fibula (*f*), being rudimentary. Such a complete union of ankle-bones with the leg is not seen in any living reptiles (see Fig. 85, C). Whilst the latter have four toes as their least complement, birds have never more than four, the fifth toe being invariably wanting. And whilst in birds, the bones of the instep unite with the lower half of the ankle to form a single bone (Figs. 85, A, *tm*, and 76, *w*), in reptiles the instep bones (or metatarsals) (Fig. 85 C, 1, 2, 3, 4) are not united together, and are distinct from those of the ankle.

FIG. 76.—SKELETON OF BIRD.

Thus much for dry details. The reader who has taken the trouble to follow this category of the personal characters of birds as compared with those of reptiles, will probably find that the somewhat extended examination will assist his comprehension of certain abnormalities in the structure of several extinct forms of bird and reptilian life; since many of the characteristic features of each class just detailed will be found to have been curiously modified and often united in the "missing links" which bind these two groups of animals together. It may be firstly asserted that the ostriches, cassowaries, and their relatives, differ from all other birds in possessing a flat shield-like breast-bone instead of the normal "keeled" structure (Fig. 76, *f*, *g*) proper to the class. Their "merrythought" is likewise incomplete, and their haunch-bones are united below or in front, instead of remaining open as in other birds. But he would be worse than an over-bold zoologist who would venture to maintain that such points of difference meant more than the merest tendency reptilewards; and the ostriches and their neighbours can hardly be denominated links which appreciably narrow the gulf betwixt reptiles and their bird kith and kin. But presuming that the zoologist, dealing with the birds of to-day, refuses assent to the idea that he can supply us with missing links between reptiles and birds, can the contents of the geologist's aviary be shown to be better adapted to supply the gap? Research here may proceed in two directions. Either we may try to discover if any extinct birds are nearer reptiles than their living allies; or, we may endeavour to ascertain if any fossil reptiles exhibit a closer relationship with birds than the reptiles of to-day. We may very profitably discuss, in brief detail, both aspects of the case.

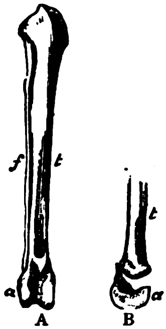


FIG. 77.—LEG AND ANKLE OF BIRD. A, in the full-grown bird; B, in the young state.

Fossil birds make their first appearance in the Upper Oolite

FIG. 78.

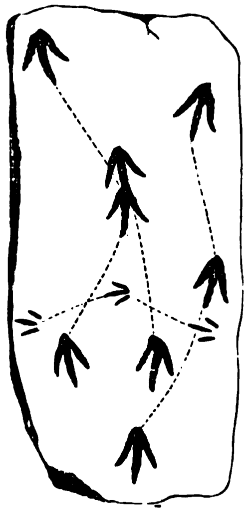


FIG. 79.

FOSSIL FOOTPRINTS FROM TRIASSIC ROCKS.

rocks—formations lying in their natural order just below the chalk.

Prior to the Oolitic epoch, however, and in the Triassic rocks of America, certain large footprints (Figs. 78 and 79), supposed by some authorities to be those of birds, are found. But these footprints may, at the same time, be those of reptiles, and it is safer at present to hold their exact nature as undetermined, and to assert that the first unmistakable bird-fossil belongs to the Oolitic period.

The Lithographic Slates of Solenhofen, in Bavaria, are rocks resulting from the consolidation of the finely powdered mud which once coated an ancient Oolitic sea- or lake-bed. On this fine-grained deposit, belonging to the Upper Oolite series, the merest traces and most delicate impressions of living organisms have been preserved—the impress of even a filmy jelly-fish having thus been brought to light. In 1861 the impression of a single feather was found, and later

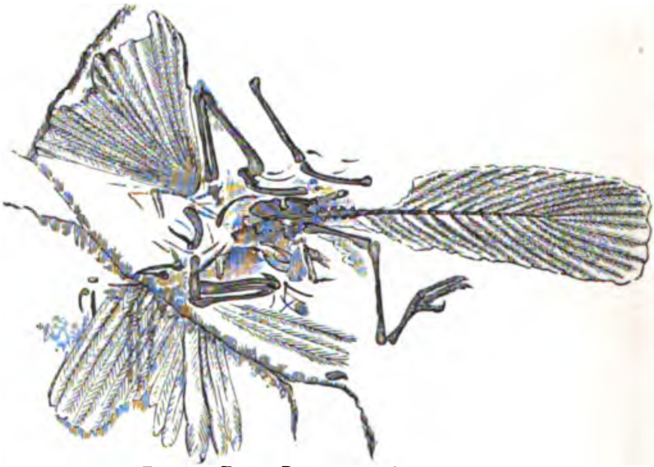


FIG. 80.—FOSSIL REMAINS OF ARCHÆOPTERYX.

on in the same year, a Dr. Häberlein of Pappenheim brought to light the fragments of a skeleton which was soon discovered to be of a thoroughly unique kind. This scientific treasure was duly purchased for the British Museum, and was named the *Archæopteryx macrura* (Fig. 80). The skull of Archæopteryx was wanting in this first specimen, but the leg, foot, pelvis, tail, shoulder, and some of the feathers are well preserved, and by these relics the materials for a strange history was in part supplied. Of the bird-nature of this creature no doubt exists. In the matter of its feathers and feet it is wholly bird-like. But it is also discovered to differ very materially from all known birds. Thus, firstly, Archæopteryx possessed a long tail (Fig. 80), exactly resembling that of a lizard, consisting of some twenty joints, each of which supported a pair of quill feathers. Then, secondly, no ploughshare-bone (Fig. 76 *d*) was developed. The fingers, united by bony union in existing birds, were free and reptile-like in Archæopteryx, and, whatever their number may have been, it is certain that these fingers were provided with reptile-like claws, such as are seen in no living bird.

Such were the details of Archæopteryx structure at hand till within the last three years or so. In 1879 Professor Carl Vogt made a communication concerning a fresh specimen of this ancient bird, found in the same deposits which afforded the previous specimen. The new specimen was singularly complete; and its wings were unfolded, as if death and fossilisation had overtaken it in the act of flight. Its examination revealed certain startling features, which only serve to confirm in an unmistakable manner the thoroughly "intermediate" nature of this animal. Its upper jaw bore two small conical teeth; the breast-bone is "reduced to zero;" and whilst its arm-bones "present no features peculiar to reptiles or to birds," its hand can be compared neither to that of a bird nor to that of a pterodactyl, but to that of a three-toed lizard. "If the feathers had not been preserved," says Vogt, "no one could have ever suspected that, from the examination of the skeleton alone of *Archæopteryx*, this animal was furnished with wings when alive." Head, neck, chest and ribs, tail, shoulder-girdle, and arm or wing, are all built on a reptilian type; the haunch is more reptilian than bird-like; but the hind limbs are those of a bird. The reptile characters unquestionably predominate in the skeleton, just as the bird-characters come to the front in the feathers.

Professor Vogt strenuously asserts that a study of *Archæopteryx* shows that it is neither bird nor reptile, but that it is a decided "link" betwixt the two classes. It is a bird by its feathers and hind limbs; it is a reptile by the rest of its structure; and it is, moreover, a bird only in so far as we regard its type as having emerged from a reptilian stock. The birds to be presently described from the American Chalk are later developments. As such, they are nearer the birds of to-day; but they retain the reptilian teeth, whilst the rest of their organisation has been evolved along the lines of bird-structure. Professor Vogt further insists on the fact that the adaptation to flight is not necessarily combined with an erect position, since the extinct pterodactyls and the living bats illustrate cases in which that position was and is not maintained. The bird-like hind feet of the *Archæopteryx* must be viewed as having been independent of flight, and as related to the possibility of sustaining the body on the hinder feet alone. In other words, we are not specially entitled to concern ourselves with the question of flight in this ancient animal; and the consideration is worth attention in dealing with the affinities of the *Archæopteryx.* Finally, as Vogt points out, there is a complete affinity betwixt the scale of the reptile and the feather of the bird. The feather is, in fact, the further modification of the scale; and we may, therefore, "imagine the ancestors of the Archæopteryx as lizard-like terrestrial reptiles, having feet with fine, hooked, free digits, showing no modification in their skeleton, but having the skin furnished at different points with elongated warts, downy plumes, and rudimentary feathers, not yet fitted for flight, but susceptible of further development in the course of generations."

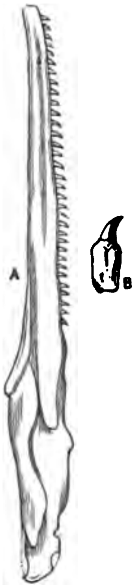


FIG. 81. HESPERORNIS JAW.

But that this odd relic of the Oolite leads us decidedly in the direction of the reptiles by its tail and its hand there can exist no reasonable doubt. Scepticism may exist on this latter point, but the doubt is neither of a learned nor of a scientific kind. We may not say that Archæopteryx actually leads us from any one bird to any one group of reptiles. It rather stands intermediately and alone; but even in its solitary position it certainly makes the gulf betwixt the two classes seem less formidable.

Next in order from the aviary of the geologist may be produced evidence of the existence of reptile-like birds in a most interesting series of fossils obtained from the Chalk of Western America by Professor Marsh. About 1871 a headless bird skeleton was discovered in the Upper Chalk of Western Kansas. This bird evidently resembled our living divers, and was duly christened *Hesperornis regalis.* Like our living ostriches, emeus, and their allies, this extinct bird possessed no keel on its breast-bone. It had the merest rudiments of wings; and certain reptile-like resemblances seen in its haunch-bones made geologists naturally anxious for the realisation of their hopes in the discovery of a complete skeleton. In 1872 fresh discoveries rewarded the patient and indefatigable search of Professor Marsh. Not only were the missing parts of the Hesperornis duly obtained, but the remains of another and still more remarkable species (*Ichthyornis dispar*) of extinct birds, were duly brought to

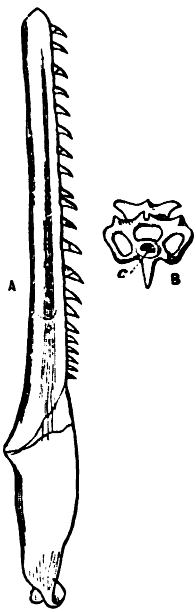


FIG. 82. ICHTHYORNIS JAW.

light. By the new discovery both Hesperornis and Ichthyornis were found to possess teeth; the former (Fig. 81) having its curved teeth (B) set in a common groove in the jaw-bones; whilst Ichthyornis (Fig. 82) makes a further advance towards perfection in dental apparatus, in that its twenty or so teeth of each jaw were lodged in distinct sockets. The importance of these facts as bearing on true reptile-like characters in birds may be readily imagined. No living bird possesses even the semblance of teeth, if we except the horny ridges of the Merganser's bill. Prior to Marsh's discoveries, no fossil bird was known to have been provided with true teeth—although indeed, in certain bird-remains, described by Owen, from the London clay (Eocene) of Sheppey, under the name of *Odontopteryx* (Fig. 83), the jaws were provided with bony projections. These projections, however, are not true teeth—which, as many readers may know, do not resemble bones, either in development or structure, being developed from the "gum" or lining membrane of the mouth, and not from cartilage, as true bones usually are. Doubtless these bony projections aided Odontopteryx to catch its finny prey, as the horny ridges

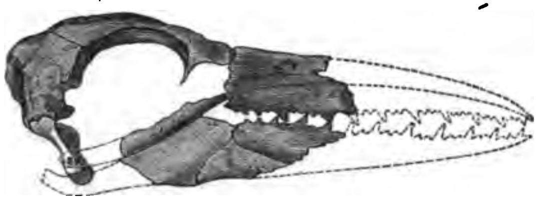


FIG. 83.—ODONTOPTERYX (RESTORED).

of the Mergansers enable them to retain the fishes they so dexterously capture. One curious bird (*Phytotoma*), a South American Leaf-cutter, certainly possesses a double row of bony projections on its palate. But even this novel and unusual addition to the list of bird-possessions bears but a faint resemblance to the bony teeth of Odontopteryx, as these latter in turn are an entirely different and relatively modern feature of the bird-type, when compared with the true teeth of their "American cousins" of the Western Chalk.

The Ichthyornis, moreover, diminishes the distance betwixt birds and reptiles in yet another fashion—the joints of its spine (Fig. 82, B.) were concave at either end (*c*), a conformation familiar to us in the joints of the fish-backbone, utterly unknown in living birds, but common enough in reptiles. This character alone, in the eyes of the naturalist, becomes invested with an importance hardly to be over-estimated as regards its reptilian relationships; and in Hesperornis, also, certain features in addition to those already noted show unmistakable marks of affinity to the reptile type. The teeth of this latter bird, set, as already remarked, in a common groove, strongly remind one of the manner in which the teeth of certain lizards are fixed in their jaws. Some of the teeth of this curious bird also exhibit the manner in which one series of teeth was replaced by another—for, as most readers know, reptiles and fishes possess an unlimited supply and a continual succession of teeth. The old teeth are ousted from their sockets by new teeth which are developed at their bases; and in the jaws of Hesperornis such a manner of tooth-formation, exactly imitating a common reptilian mode of renewal, is to be plainly seen. The tail of this great diver of the Chalk seas was, lastly, like that of the Archæopteryx of the Oolite epoch, and exhibited a very different structure from the caudal appendage of existing and of other fossil birds. At its middle and under parts the joints of the tail present long projections of flattened shape, which strongly suggest the idea of the tail having been a rigid unyielding member in so far as a side movement was concerned, but, like that of the beaver, being probably mobile in a vertical direction, and being thus of use in the diving movements of its possessor. The last joints of the tail were massed together, but in a fashion different from that in which the "plough-share-bone" of living birds is formed.

In so far as the birds themselves have rendered an account of their past history, it is clearly seen that their affinities to reptiles become very strongly marked in various directions, especially in the structure of the spine, and in the possession of true teeth. Ichthyornis, in the matter of its hollowed spine-bones (Fig. 82, B, *c*), and in that of its socket-implanted teeth, is a more modified and more truly reptile-like bird than Hesperornis. This latter again, approaches much nearer reptiles than Odontopteryx (Fig. 83) of the London Clay, which latter, as becomes its nearer approach to the existing order of affairs, presents a less marked relationship with "the dragons of the prime."

FIG. 84.
RESTORATION OF COMPSOGNATHUS.

But what evidence, we may lastly ask, do the reptiles afford on their side of any tendency towards the bird type? Have the reptiles remained as passive to advance and evolution, as they would appear at first sight to remain to-day; or does their history but repeat the changes and variations exhibited by their bird-neighbours? Let the history of the reptile class in the past answer these queries. A considerable number of fossil reptiles are ranked to form a distinct order or division, marked by various near approaches to the structure of birds. A single example of this curious group will suffice to show the intermediate nature of its included forms. Once again the Lithographic Slates of Solenhofen yield a rich reward to geological investigation, and present us with the fossil skeleton of an animal which in the flesh attained a length of about two feet. This is the *Compsognathus* (Fig. 84) of the geologist—a long-necked reptile, possessing a small head, the jaws of which, however, were armed with teeth. Its fore limbs were short, its hind limbs being long and bird-like. Like that of birds, its thigh-bone (Fig. 85, B, *fe*) is shorter than its leg-bone. As in birds (Fig. 85 A), the upper half of the ankle-bone of Compsognathus (Fig. 85, B, *as*, *ca*) unites with the lower part of the leg; but the lower half of the ankle (*td*) was not, as in birds, united with the instep-bones, or metatarsals (1, 2, 3, 4), which are three or four in number, long and slender, and which, in Compsognathus, support the second, third, and fourth toes. A mere trace of the instep-bone of the fifth toe exists, and the first or great toe is of small size. In all birds the fifth toe is entirely wanting. Looking at the structure of Compsognathus, and of its fossil allies, such as Iguanodon, little or no doubt can be entertained that these reptiles were capable of resting on their hind limbs, in bird-like fashion, and of walking, or hopping, after the fashion of the feathered bipeds, to

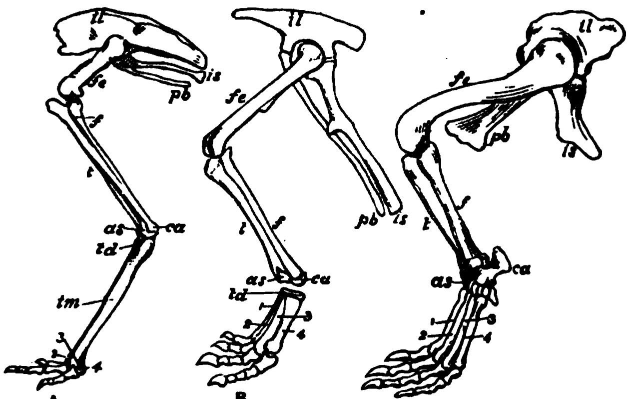


FIG. 85.—(A) HINDLIMBS OF BIRD; (B) EXTINCT REPTILE; AND (C) CROCODILE.

which indeed, by a use of the imagination, strictly scientific, we may regard this reptilian group as having in due time given origin. It is unquestionably to the struthious birds, that is, to the ostriches and their allies, that this curious reptile bears the closest resemblance; and a comparative glance at the hinder extremities of the crocodile, bird, and its reptilian neighbour (Fig. 85), will suffice to show the marked resemblances and gradation which connect, and at the same time distinguish, this curious series of forms. The Compsognathus limb stands intermediate betwixt the saurian (Fig. 85, C) and the bird (A); and, strictly judged, is comparable most nearly to that of the unborn chick. Those "dragons of the prime" known as Iguanodon and Megalosaurus, from the Chalk and Oolite, are near relations of Compsognathus. When we think of the size of these reptiles, which attained a length of from forty to sixty feet, and of the probability that, like their diminutive neighbour, they may have walked on two legs, the origin of the giant footprints (Figs. 78 and 79) of the Triassic Sand-stones would appear to present no special difficulties in the way of satisfactory solution.

Mention must here be made of the curious Pterodactyls (Fig. 86), or those extinct reptiles of the Lias, Oolite, and Chalk, in which a wing-membrane or fold of skin, similar to that seen in bats, stretched from an outer and enormously elongated finger of each hand to the fore-limb,

FIG. 86.—SKELETON OF PTERODACTYL. (The wing membrane in black.

sides of the body, and hind limbs, and between the hind limbs and tail. By aid of this wing-membrane these literal "flying dragons" must have winged their way through the air with ease and speed. Their breast-bone was keeled like that of the bird (Fig. 76, *f*, *g*); their shoulder-girdle was bird-like; and their bones, as in birds, were hollow, and were filled with air in place of marrow. The Pterodactyl brain was essentially bird-like, but the hind limbs and pelvis were reptilian, and unlike those of the bird; and these flying dragons possessed prominent jaws, usually furnished with socket-implanted teeth. The Pterodactyls are thus not markedly bird-like in any sense. They do not lie in the direct line, nor form one in the series of links between birds and reptiles, but apparently represent a bird-like but independent offshoot of the reptilian branch. In any view of their nature, however, they serve to show plainly and forcibly the modification of the reptilian type for flight. It requires but a limited draft upon speculative philosophy to support the belief that reptile modification in another direction, and certainly at an epoch anterior to the appearance of the Pterodactyls, probably produced the modified birds of which our existing ornithology is the collective product.

Space fails us in the endeavour to describe other examples of animals which from their anomalous structure seem to connect very diverse types of living forms. Mention might be made of the interesting fact that the apparently distinct groups of living and extinct crocodiles are linked together in a very exact fashion by their bodily structure; or, conversely, that it is easy to conceive of the varied crocodiles known to science, as having originated by modification of a common type. The mere mention of such fishes as *Lepidosiren* and *Ceratodus*, linking their class to that of the frogs or amphibians; or of such a mammai as the *Ornithorhynchus* (the "Duck-billed Water-mole" of Australia), with its bird-like skeleton, and other structures of avian nature, suggests to the naturalist the idea that such anomalies are after all only to be accounted for by a theory of nature which postulates the necessity for "links" binding together groups which, at first sight, appear of widely varied and distinct nature.

Summing up the results of this investigation in search of "missing links," what may be regarded as the results of our labours? and to which side does the weight of evidence lead?—to evolution and modification as the parent of all that is in living nature, or to rigidity and fixity of type and form, as the rule and way of life at large? Judged by a very ordinary standard of value, the evidence appears overwhelmingly strong in favour of the former view. The demand for "missing links," as necessary features of the evolutionist's scheme of creation, is not left unanswered where just cause is shown for the production of these connections between the life of the past and that of the present. There is neither wildness nor absurdity in the idea that the bird-stock began in animals resembling Compsognathus and its neighbours, and that through modified bird-forms—probably resembling the living ostriches and their allies—the further and higher development of our existing bird life was gradually evolved. The exact stages of such development we are unable to picture. The sketch is as yet in meagre outline; but the outlines foreshadow tolerably well the actual details of the finished work. And what is true of the relations between reptiles and birds, or of those between the various races of crocodiles—which, it is important to note, living and extinct, are bound together in a series almost as graduated and complete as are the horses and their progenitors—what is true of the connecting links betwixt quadrupeds that to-day appear distinct and separate, must by every consideration, alike of logic and common sense, be held to apply with equal force to the entire world of animal and plant life. There is no law of evolution for one group, and of special creation for another. There can be logically postulated no evolution for the lower races, and some process of "creation" for the higher forms of animal life or for man himself. Uniformity and sequence exist wholly, or not at all. "If one series of species," says Huxley, "has come into existence by the operation of natural causes, it seems folly to deny that all may have arisen in the same way." The unbiassed mind, contemplating the varied phases of living nature, will stand in no dread of any conclusions respecting the order of this universe, to which evolution may lead; for, after all, evolution, in tracing out the ways of nature, is but the handmaid of truth, and it is with the truth as it is in nature, that the earnest mind will most desire to close.

IX.

THE EVIDENCE FROM DEVELOPMENT.

I.—THE EARLIER STAGES IN THE LIFE-HISTORY OF ANIMALS.

Among the many features which mark the varied universe of life, none are more universally recognised, or more typical of the living world, than those which herald the production of a new being, and which usher a new form upon the stage of existence. From the shapeless mass of protoplasm that crawls over the water-weed as a microscopic speck, upwards to man himself, the varied processes of development are laid down in orderly sequence and along lines of special kind. Every living being, animal or plant—animalcule and whale, the humble lichen and the giant sequoia alike—passes through a definite series of changes before attaining the form and likeness of the parent which gave it birth. In virtue of such changes it assumes that parental form. These changes, occurring in orderly array, mark its pathway from shapelessness and physiological nonentity to the characteristic form of its race. It is development which moulds—

> The baby figure of the giant mass,

and from the minute beginnings of life evolves the highest of earth's denizens, or directs the production of the teeming swarms of animalcules that people the stagnant drop, and pass an existence none the less interesting or important because often all unknown to the larger and higher world without. It is this same process of development which, as one phase of living action, draws the sharpest and clearest of boundary lines between the world of life and that of non-living matter. Growth and increase are truly represented in the inorganic world ; but these processes are different in kind from the actions which stamp the development of the animal or plant. The birth of a crystal, although regulated by definite laws, is, after all, a matter of outside regulation alone, and one in which the crystal itself is but a passive agent. New particles are added to the outside surfaces of the old and already formed particles ; and crystal and stalactite thus grow mechanically and by accretion, but without active participation in the work destined to mould and form their substance.

Very different are the forces and laws which regulate the production of the living form. Here the changes of form and the building of the frame are marked out in plain and definite pathways by laws essentially independent of external conditions. True, the development of the living form may be retarded by cold or favoured by warmth, but these conditions leave unaffected the course and direction in which it is destined to pass towards the form and belongings of the parent which gave it birth. Stamped ineffaceably on the pages of its life-history, the way of the animal or plant towards maturity is written for it, not by it. Internal forces and hidden but all-powerful laws of life direct its progress, and ultimately evolve the perfect being from the shapeless germ, in which its past as derived from its parents, and its future as depending in some degree at least upon itself, meet in strange and incomprehensible union. The development of a living being may be further shown to be merely a part of the wondrous cycle in which life appears to direct its possessors. From the egg or germ, development leads us to the perfect being. Next in order we consider its adult or perfected history; and in due time we may discover the adult existence to merge into that of the immature state in the production of germs, in the development of which its own life-history will be duly repeated. The period of adult life in this view merely intervenes betwixt one development and another, and serves to connect those ever-recurring stages in the life-history of the race which it is the province of development to chronicle and record.

As a necessary item in the perfect understanding of animal and plant history, it may readily be understood how important a place development occupies in modern biology. Nor is the interest of the study excelled by its importance. The mystery of life itself might well be thought by the older physiologists to resolve itself into an understanding of the fashion in which Nature moulded and formed her varied offspring. The manner of development might be almost expected to explain the mystery of being; but the problem of life is left as insoluble as before, after the course of development in even the lowest grades of existence has been traced. The history of development but environs the puzzles connected with life and its nature. It leads us to the beginnings of life, it is true, but it leaves these beginnings unaccounted for, and as mysterious as before. It explains how this tissue or that, this organ or that, is fashioned and formed; and as we watch the formless substance giving birth to the formed, the indefinite evolving the defined, we might well be tempted to think that the "why" of nature was explained by the "how." Yet the springs of life and vital action remain hidden as of yore, and the exact origin of life is a mystery as insoluble as when the thoughts of men were first directed to its elucidation.

Apart, however, from the admission that the study of development has not brought us nearer to the solution of the question, "What is life?" the investigation of the life-histories of animals and plants is fraught with high importance in another sense and in other aspects of the scientific interpretation of nature. The early observers hardly imagined that, in their researches into the formation of the chick, they were laying the foundation of a study which in future days would be destined to aid man's comprehension of his own origin and that of all other living beings. Aristotle's observations upon the developing chick, and his bestowal of the name *punctum saliens*, or "beating point," upon the first beginnings of the heart in the embryo bird, were in truth fraught with an importance to succeeding generations which that philosopher could barely have realised had he possessed any prophetic foresight whatever. And no less would Harvey himself have been astonished had he beheld the results to which the pursuit of his favourite study has led in these latter days. It was that great philosopher himself who first maintained that the chick was developed, not from the white of the egg, but from a minute speck or scar on the surface of the yolk, known as the *blastoderm* or *cicatricula.* In felicitous terms Harvey enunciates his opinion that the "Medici," or disciples of Galen and Hippocrates, were in error when they supposed that such important structures as brain, heart, and liver were first produced, simultaneously, as minute sacs or vesicles; and he disagrees with Aristotle, in respect that the latter had maintained the *punctum saliens* [or *punctum sanguineum*], or heart, as the chief agent in forming the structures of the new being. Harvey ascribed to the blood itself the formative power in developing the chick. With Aristotle, however, Harvey is in perfect agreement in believing that the chick is formed, not by the sudden formation of new parts outside the already formed organs, nor by the growth of a miniature and perfectly formed embryo into the larger chick, but by the gradual development and elaboration of uniform and like matter into the new and varied parts and organs of the bird.

Such were Harvey's views regarding the nature of development. Of the supreme interest exhibited by the discoverer of the circulation in this study, no better proof could be cited than his own words when he maintains "that it is most apparent that, in the generation of the chicken out of the egge, all things are set up and formed with a most singular providence, Divine wisdom, and an admirable and incomprehensible artifice." Harvey's doctrine of development received the name of *Epigenesis*, which the physiologist himself defines, in his forty-first "Exercitation," as "the additament of parts budding one out of another." Contrasted with this opinion, is that of such physiologists as Malpighi and Leibnitz. They held that the body of the chick could be traced in the egg before the first rudiment of the heart appeared; and that from the first formation of the egg, and prior to incubation, the young bird was to be found perfectly formed therein. Thus, by Malpighi's view, the process of development was merely one of the expansion, unfolding, and enlargement of parts already formed; and this idea became known as that of Metamorphosis, in contradistinction to Harvey's theory of "Epigenesis." So, also, Bonnet maintained the existence of a miniature chick in the egg from the first moment of its formation. Subsequent growth and nutrition merely expand the elements and parts of this germ into those of the adult; and thus Bonnet declares the process of development to be merely one of "Evolution." Thus the doctrine of "Epigenesis," as enunciated by Harvey, becomes opposed to that of "Evolution," as maintained by Bonnet and Haller—the development of new parts and structures from a structureless substance, as distinguished from the mere enlargement and unfolding of the miniature but already formed elements of the frame.

But when Bonnet, in 1762, in his work entitled "Considérations sur les Corps organisés," was elaborating his theory of "Evolution" and less rational views on "Emboîtement"—a theory holding that each germ is the receptacle of the germs of all future beings of its race—Caspar Friederich Wolff had already lent his aid towards placing the Harveian views on a secure and stable basis. Wolff showed that the scar on the hen's egg consisted of particles amidst which no rudiment of an embryo chick could be traced. He further demonstrated the changes whereby the chick was built up from these cells, and showed the process of development to be truly one wherein new parts were formed in succession, and added to the already formed organs. Succeeding Wolff came Pander, who filled in the outlines his predecessor had so well sketched out by detailing the earlier stages and processes seen in the formation of the young bird. From Pander came the name *blastoderm*, given then, as now, to the substance or formative material resulting from early changes in the "egg-scar," and from which material all the parts of the young animal are formed. This observer also cleared the way for his successors by pointing out the presence of the three layers into which the blastoderm divides; each layer bearing an important share in the formation of the tissues of the developing being. To Pander came in due time a worthy successor, who may be said to have laid the solid foundations of the study of development as prosecuted in modern times. This was Von Baër, whose labours each physiologist and naturalist of to-day must hold in grateful remembrance. He it was who, besides perfecting the details already to hand, discerned the important fact that the highest animals are developed from eggs or germs resembling in essential nature those of the lowest. But perhaps the greatest triumph of discovery and research as represented by Von Baër's labours resulted in the enunciation of his "law of development," which may be briefly expressed in the phrase that "development proceeds from the general to the special."

To rightly understand the purport of this axiom, our preliminary studies in the constitution of the animal kingdom must be borne in mind. The animal world, as we have seen, is divided into a number of great types, the most consistent and most firmly established of which are the *Vertebrates*, including the "backboned" animals from fishes to man; *Molluscs*, including shell fish, such as oysters, cockles, snails, and cuttle-fishes; and *Annulose* animals, or *Articulates*, represented by animals with jointed bodies, such as worms, insects, centipedes, crustaceans, &c. Now, if the development of a number of animals belonging to any one of these three divisions is observed, the egg of each animal is seen to pursue the even tenor of its way, and to pass at first through exactly the same stages of development. Up to a given point, the stages in the development of all Vertebrates, for example, are essentially similar. Sooner or later, however, development begins to specialise its course, and hence arise the differences which mark the adult forms. So also with Molluscs, which in their earlier stages pass through essentially the same changes, but sooner or later diverge in their course; each organism passing on its own way to assume the special features which characterise the adult. Such was the important generalisation of Von Baër. Succeeding research has but tended to establish Von Baër's doctrine, whilst it has also enlarged the conception he was the first to promulgate. It is now known that there are stages in early development which are common to the eggs or germs of all animals alike; and that, from the common track thus pursued up to a given point by animal life at large, each group of animals ultimately diverges on its own special way of life. Von Baër's generalisation has thus come to include the whole animal world, and has in recent times tended powerfully to support the doctrine which would explain the origin of living beings by presuming their descent from pre-existing forms, and their relation with each other as twigs, boughs, and branches of a great connected tree.

The relation of development and its study to the hypothesis of evolution is thus easy of determination. It is a perfectly reasonable and most natural conception that in the development of a living being we should obtain some clue to the history of its origin and to the birth of its race. If its origin be a subject of research at all, any information concerning the stages through which an animal or plant becomes the adult organism, and by which it advances from literal non-existence to the staid solidity of mature form and perfect life, should, by analogy the most natural, be regarded as a veritable mine of knowledge concerning its own beginning—and, by further analogy, regarding the beginnings of the world of life at large. Upon such a thought is founded the dependence which modern biology is led to place upon development as a clue to the evolution of living beings. Succinctly expressed, it is thus held by evolutionists in general, that *the development of the individual is a recapitulation in brief of the development of its species or race.* The history of the production of the individual is viewed as "the abstract and brief chronicle" of the changes and developments through which its race has passed in prior ages of this world's existence. It is true that such a history often appears meagre and imperfect. Some of its phases become altered in the lapse of time by the influence of surroundings acting favourably or the reverse upon successive generations. As the lines of human progress are not always easy to trace, so those of animal advance and evolution frequently appear blurred and indistinct. But on the whole the record is tolerably complete. The gaps in animal histories do not affect the main question at issue—namely, that, as Darwin says, the embryo or young animal "is a picture, more or less obscured, of the progenitor, either in its adult or larval state, of all the members of the same great class." That such a study must teem with interest, is a remark scarcely requiring mention. Nor may it be regarded as other than a triumph of scientific research, when development may be seen to demonstrate how individual history repeats the history of the race; and how the living world of to-day once existed in simpler guise, and in the dim obscurity of the past—

> Lay hidden, as the music of the moon
> Sleeps in the plain eggs of the nightingale.

Although the study of animal development is in many ways an intricate branch of research, there exists no difficulty in comprehending the broad outlines which mark the building of the body in the higher as well as the lower forms of animal life. If we watch the development of some animal—such as a sponge—belonging to the lower grades of organisation, we may be enabled to distinguish certain stages which not only mark sponge-development, but also that of animal life at large. The simplest form of a sponge exists as a cup-shaped body attached to some fixed object. Such a form of sponge (*Olynthus*) is depicted in Fig. 87, 7. The walls of this cup, consisting of two layers, are perforated with holes or "pores" (*p*), which open into the substance of the cup, and thence into the interior, which communicates with the outer world by the wide mouth or "osculum" (*os*). This sponge-cup consists of two layers, of which the inner is provided with delicate filaments, resembling eyelashes in miniature, and named "cilia." These cilia by their constant movement cause currents of water to flow into the sponge by the outer "pores" (*p*), whilst by the same movement, the water is driven outwards by the mouth (*os*) of the cup. In this way the living particles of the sponge are supplied with nutriment; and the comparison of a sponge to a kind of submarine Venice, with canals and waterways, on the banks of which the inhabitants live, is thus seen to be fully justifiable. The development of such an organism takes place through the production of eggs (*f* 7), which are developed in the tissues of the parent sponge, and which are merely specialised portions or cells of the inner layer of the parent body. The sponge-egg (Fig. 87, 1), it must be remarked, presents the essential elements seen in the eggs or germs of all animals. It is a little speck of protoplasm, imbedded in which

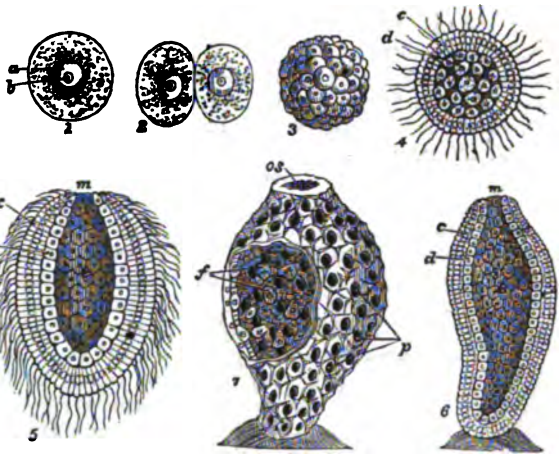


FIG. 87.—DEVELOPMENT OF A SPONGE (*Olynthus*).

we find a smaller body known as the *germinal vesicle* (*a*), and this latter in turn contains a still more minute particle, the *germinal spot* (*b*).

When such an egg is about to undergo development, the first changes which occur in its substance are those collectively named "segmentation." The egg is then seen to undergo a process of division (2). It divides internally and successively into two, four, eight, sixteen, &c., cells or divisions; these portions ultimately becoming so numerous, that the egg at the close of its segmentation, from its resemblance to a mulberry, has been named a *morula* (3). Soon the outer cells become elongated and provided with cilia (4), and by means of these filaments the young organism swims freely about in the water. In this stage it is known as the *planula* (4). Next in order a central cavity and then a mouth (5, *m*) are formed, this aperture leading into the cavity (*e*) of the cup. It is now named the *gastrula*; and its body is seen to consist of two typical layers, an outer or *ectoderm* (*c*) and an inner or *endoderm* (*d*). These two germ-layers, as we shall hereafter note, are common to all animals in the course of their development—indeed, the formation of the embryo takes place through the subsequent development and elaboration of these two primary structures. Thereafter, this sponge-embryo will attach itself to some fixed object; the outside cilia, no longer required for locomotion, will disappear, and it will assume its so-called *ascula* form (6). Other and new cilia will become developed in the inner or lining membrane of the body; the wall of the cup will next become perforated with pores; and with the inauguration of the inward and outward circulation of water, the ordinary features of adult sponge-existence (7) will thus have been attained.

Such being the course of affairs in one of the simplest of animal developments, we may briefly summarise the stages included therein. These stages consist firstly of the *segmentation* of the egg, which process produces the mulberry-like mass or *morula*. Next in order we find the *planula* with its two layers and its outer cilia. Then succeeds the *gastrula* possessing an internal cavity, into which a mouth shortly opens; and with the formation of pores and internal cilia, the form of the adult sponge is duly produced.

Selecting a form of animal life widely removed from the sponges, let us briefly investigate the stages through which the sea-squirts or *Ascidians* attain the somewhat prosaic features which mark their adult existence. The adult and ordinary sea-squirt presents itself as a bag-shaped organism (Fig. 88) rooted to stones at low water mark, and bearing two apertures (Fig. 88, *m*, *a*) on its upper extremity. The resemblance of these ascidians to an antique wine-jar (*askos*) is forcible enough; and the characters from which the familiar name "sea-squirt" has been derived are also readily discernible. When prying humanity, even in the legitimate guise of the scientific investigator, presumes to handle the ascidian constitution too roughly, these animals are given to eject water from the orifices of their jar-like bodies—a playful habit the unpoliteness of which, from its reflex and unconscious nature, even other than scientific investigators may well excuse. "Sea-squirts" are usually regarded by naturalists as near relations of the oysters and other molluscs; but their differences from the familiar shellfish are so numerous and so important that their separation from molluscs as an aberrant type of animals and their enclosure, even in the Vertebrate group, is a perfectly legitimate procedure.

FIG. 88.
SEA-SQUIRT.

Again the aptness of the Harveian motto, "Omne vivum ex ovo," is apparent, when we find that sea-squirt history begins with the production and fertilisation of an egg or germ (Fig. 89, 1), which resembles that of the sponge and of all other animals, man included, in possessing a germ-vesicle (*a*) and germ-spot (*b*). Once again, as in the sponge, we meet with the process of egg-segmentation (2), resulting in the production of a morula (3). Then the cells of the morula arrange themselves to form the two layers (Fig. 89, 4, *ec*, *en*) as in the sponge, the outer layer being pushed inwards upon itself so as to form a central cavity (*d*), much as a night-cap is so modelled to fit the head. Thus our "gastrula-stage" (4) once again appears, and in the life-history of an animal very far removed from the sponge in structure and relationship.

From this stage, common alike to sea-squirts and sponges, ascidian development begins to specialise itself. Another opening or depression (*b*) appears above the opening which formerly led into the gastrula-body. Within this depression, which at first communicates by an opening (*o*) with the exterior, a part of the outer layer is contained, and finally becomes shut off from the other portions of that layer. This separated and confined part (*b*) of the outer layer becomes the nervous system of the sea-squirt. Next in order, we find the body to extend itself behind, so as to form a well-marked "tail" (Fig. 89, 5), within which a rod-like body, the *urochord* (*n*), is formed. Overlying this body at its front portion, the nervous system (*f*) just mentioned is further elaborated; and muscular elements become developed in connection with the tail and its contained rod.

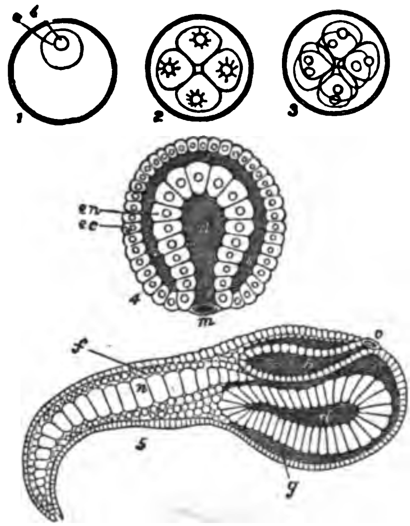


FIG. 89.—DEVELOPMENT OF SEA-SQUIRT.

Meanwhile the beginnings of a digestive system (*d*) and of the breathing-sac (*g*) are being formed, and at this stage the young sea-squirt appears to be actively mobile, and to swim freely in its tadpole-like stage of development. Fixing itself thereafter by specially developed points of attachment, there begins a process of apparent degeneration in our as yet undeveloped ascidian. The tail wholly disappears, and the nervous system degenerates until but a mere fragment remains; and with an alteration of the form of the body, and some modification and further development of the other systems of organs (such as the digestive apparatus and heart), the larval ascidian becomes the mature sea-squirt.

It is of interest to note that in a few aberrant members of the sea-squirt group the larval or immature characteristics are retained throughout life. Such are the Appendicularians (Fig. 90), which, although ranked as veritable sea-squirts, retain, as a permanent belonging, the tail (*t*) which their neighbours possess only in the days of their youth. Within this permanent tail the notochord (*n*) appears developed as in the fleeting appendage of other sea-squirts, whilst the other organs of sea-squirt existence (digestive system [*s*], heart [*h*], &c.) are fully developed. From the possession of this notochord these curious animals appear as unique invertebrates, and stand alone amongst their fellows as presenting the closest resemblance to the vertebrate animals. In the Appendicularians we may perceive the existing representatives of the stock and ancestry which gave origin alike to the fixed sea-squirt race and to the great vertebrate group itself. These "permanent larval forms," as Appendicularia and its neighbours are termed, thus present us with the least modified members of their class,—with the primitive and unchanged organism whose development in other directions has produced the highest races of living beings. Of these organisms Darwin himself remarks that, "if we may rely on embryology, ever the safest guide in classification, it seems that we have at last gained a clue to the source whence the vertebrates were derived. We should then be justified in believing that at an extremely remote period a group of animals existed, resembling in many respects the larvæ of our present Ascidians, which diverged into two great branches—the one retrograding in development and producing the present class of Ascidians, the other rising to the crown and summit of the animal kingdom by giving birth to the Vertebrata."

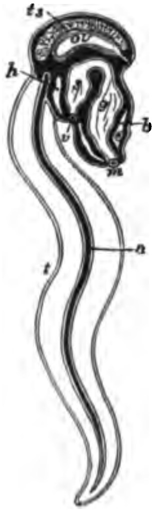


FIG. 90. APPENDICULARIA.

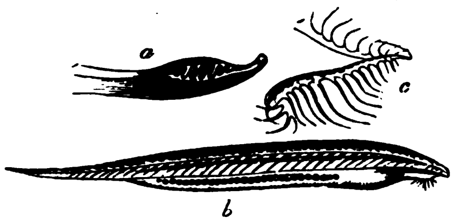


FIG. 91.—AMPHIOXUS, OR LANCELET.

Ascending now to the confines of the Vertebrate sub-kingdom of animals, we may trace the development of the curious little fish known as the Lancelet or *Amphioxus* (Fig. 91, *b*)—a form interesting not merely as being at once the lowest fish and Vertebrate, but as evincing in its development a most marked likeness to that of the sea-squirt, whose manner of entrance upon the stage of life we have just studied. The lancelet is a little fish attaining a length of one or two inches, and found inhabiting sandy coasts in various parts of the world. Its body is pointed at either extremity, and, save for a narrow fin bordering the upper and part of the lower surface of the body, no traces of the appendages commonly seen in fishes are to be found. This fish occupies the position of a very singular and anomalous member of the Vertebrate series. Unlike most of its congeners, it has no skeleton or backbone, a mere soft and gelatinous chord, termed the *notochord*, existing in the place of and representing the spine. It has no paired fins or limbs; it wants a heart; it has no skull or brain; and its organs of sense are represented by mere pigment-spots for eyes; whilst the mouth possesses a series of filaments (*c*) probably subserving the sense of touch. This little animal would seem thus to hover, as it were, on the outermost confines of Vertebrate existence. Its adult characters resemble the rudimentary traits of other Vertebrates; and in respect of its entire structure, and still more so of its development, it may be said to be a connecting link between Invertebrates in general and sea-squirts in particular on the one hand, and the Vertebrate sub-kingdom on the other.

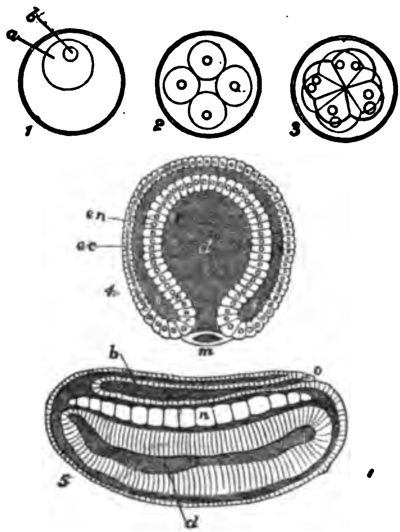


FIG. 92.—DEVELOPMENT OF LANCELET.

Like all other animals above the very lowest, the lancelet's history begins with the production of the germ or egg (Fig. 92, 1), which exhibits in its essential structure the closest similarity to that of the sponge or ascidian.

The first changes to be witnessed in the developing egg of the lancelet consist in the complete division (Fig. 92, 2, 3) of its substance. Segmentation of the egg of the lancelet is on an exact parallel with that of the egg of the sponge or the sea-squirt. We shall presently note that this segmentation is also imitated, completely or in part, in higher forms of life. As in the sponge, the "blastoderm" is duly formed; the infolding of this blastoderm and the formation of the pocket-like "gastrula" (Fig. 92, 4, and Fig. 89, 4) taking place exactly as in the development of the sea-squirt. Furnished with its eyelash-like cilia, this gastrula-lancelet swims freely in the surrounding water. Not a trace of its vertebrate character can be observed at this stage. It might be the forward progeny of a worm, or might be ranked as a developing snail; whilst if it were alleged to be an embryo star-fish, or a baby sea-squirt, the zoologist would probably own his inability to say which assertion was correct, or most in accordance with the appearance of this curious organism.

The succeeding course of events to the gastrula stage brings an elongation of the body, and from the inside or pocket-like cavity of the gastrula (4, *d*) the digestive tube of the future lancelet (5, *d*) is seen to be gradually formed. Then, also, appear the first marks and traces of its vertebrate relationship, and of its kinship with the aristocracy of the animal kingdom. The flattened aspect of the body now shows a tendency to develop two ridges or projections, which soon meet and unite in the middle line to form a tube (Fig. 92, 5, *b*), enclosing the nervous axis. This nervous tube remains open for a time in the lancelet, as depicted at *o*, Fig. 92. The body of the young fish now assumes somewhat of the appearance of a flattened cylinder. It resembles closely the young sea-squirt, and, like the latter, possesses in its back region, a rod-like body, the *notochord* (5, *n*). In the lancelet, however, the notochord extends completely from head to tail. The identity of the two developing bodies may be best demonstrated by a comparison of their longitudinal sections in Figs. 89 and 92 (5, 5), where the arrangement of parts and organs is seen to be essentially similar.

The next change results to the fore-part of the body, where the throat is seen to become cleft or perforated by the gill-slits—a sea-squirt feature again being apparent in this latter phase of development. It is equally curious to note that similar clefts—to be more specially alluded to hereafter—appear in the development of all other Vertebrates, including man; these clefts in fishes bearing gills, but in reptiles, birds, and mammals becoming obliterated. Ultimately the free-swimming lancelet assumes habits of more staid character. The notochord, which in most other and higher Vertebrates is replaced by the spine, remains in the lancelet as the permanent representative of the backbone, just as in Appendicularia (Fig. 90), among the sea-squirts, the "urochord" persists throughout life. And with the appearance of the systems and organs characteristic of its adult existence, the preparatory stages of lancelet life may be regarded as having been completed. Thus it is certain that the development of the lancelet, whilst clearly that of a vertebrate animal, is also seen to produce a low type of vertebrate organisation, and to present unmistakable affinities and likenesses to the development of the sea-squirts and of other invertebrate animals. Noting the absolute likenesses which exist between the development of the sea-squirt and lancelet, there seems every justification for the scientific belief that both animals have arisen from a common stock. The gulf between Vertebrate and Invertebrate life in this view, no longer exists; and the lancelet may be legitimately regarded as the parental form of all Vertebrates, from the fish to man.

Still higher in the vertebrate scale do our researches in development lead us when we approach the study of the chick and its early life-history. And what is true of the chick's development is, with greater or less modification of details, true of the production of every

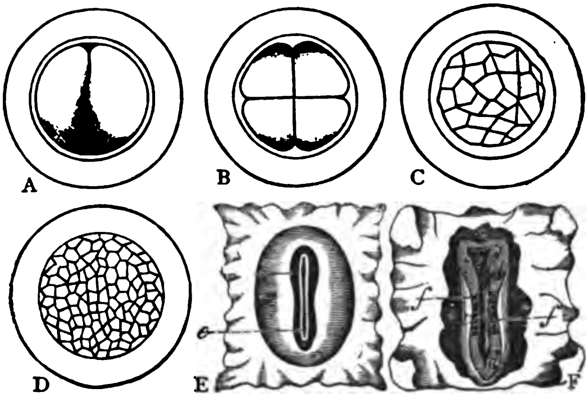


FIG. 93.—DEVELOPMENT OF VERTEBRATE.

other vertebrate animal, man included. In the developing egg of the bird, the yolk undergoes segmentation (Fig. 93, A, B, C, D), as in the sponge, ascidian, and lancelet; but the process is partial in the bird, whilst it affects the entire egg-mass in the development of lower life. The blastoderm is duly formed as the result of segmentation, and from this substance—seen in the *cicatricula*, or scar of the egg—arises the future fowl; the great mass of the yolk and white serving as nutrient material for the developing bird. Soon, the cells of which the blastoderm is composed are seen to form themselves in three layers

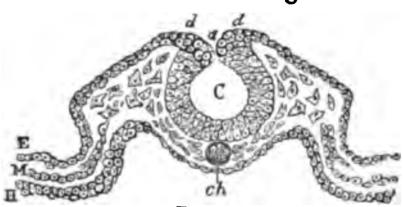


FIG. 94.
SECTION THROUGH A DEVELOPING VERTEBRATE.

(Fig. 94, E, M, H): an outer layer or *epiblast*; a middle layer or *mesoblast*; and an inner layer or *hypoblast*. It may be well to remark at this stage of our inquiries the part played by each of these three layers in the formation of the young animal. From the epiblast arise the outer skin and the nervous system. The superficial layer of the body, and the great internal nerve-centres governing the frame, its movements and vital processes, thus arise from one and the same layer—a fact appearing to argue in favour of the origin of the nervous system

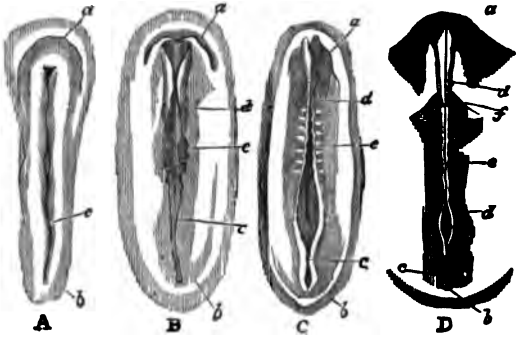


FIG. 95.—DEVELOPMENT OF CHICK.

of Vertebrates from a layer which in anterior stages of existence (as in the animalcules of to-day) originally formed the outer and sensitive margin of the body. From the mesoblast or middle layer arise the bones, muscles, blood-vessels, the under skin and other parts; whilst the hypoblast or under layer gives origin to the lining membrane of the digestive system, and to such digestive organs as the liver, pancreas, &c.

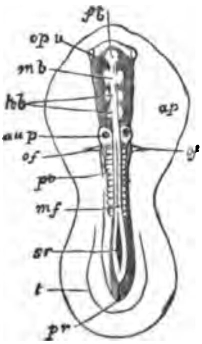


FIG. 96.—EMBRYO-CHICK (viewed from above).

About the sixth or eighth hour of incubation, these three layers of the blastoderm in the chick are duly formed. Very rapidly succeed the changes which result in the production of the chick itself. A groove (Fig. 95, A, *c*, and 93, E, *e*) soon appears on the surface of the blastoderm, this furrow being known as the "primitive groove," and constituting the keel of the body, so to speak. The edges of the groove finally grow together (Fig. 95, B, *d*), and convert the groove into a canal (Fig. 94, C). A portion of the epiblast is pinched off from the remaining portion, and being included within the tube thus formed, duly gives origin to the brain and spinal cord. As two projections of the blastoderm grow upwards to form the spinal region, so two folds grow downwards, and thus tend to form the body-walls of the young animal. Contemporaneously with these changes we find a structure of high importance to be gradually formed in the back region of the chick. This structure is the "notochord," a rod-like body (Fig. 94, *ch*), composed of a string of cells, which lies just beneath the first-formed tube (c), or that containing the nervous rudiments. The formation of this notochord cannot but forcibly call to mind the similar string of cells which appears in the course of development in the sea-squirt's larva; such a similarity being of too marked a character to admit of its being regarded in the light of a mere coincidence. On each side of the notochord the elements of the spine, in the shape of little cubical vertebræ (Figs. 95, C, *e*; 93, F, *f*; and 96, *pv*), are duly formed from the middle layer or mesoblast. The notochord itself—a permanent structure in such fishes as the lancelet, sharks, dog-fishes, &c.—gradually disappears in the chick; its retrogression being apparent after the sixth day, whilst it is found to have entirely disappeared at the time of hatching; whatever of its substance remains being absorbed in the formation of the spine. The folding of the blastoderm in front and behind soon specialises the head and tail (Fig. 96, *t*) of the young animal; the head extremity presently showing three swellings (*fb*, *mb*, *hb*), or dilatations—from which the brain is duly formed—and bending downwards in a highly characteristic fashion. Brain-development is accompanied by the formation of organs of sense, such as the nose, eyes (*op v*), and ears (*au p*), which arise as pocket-like ingrowths from the epiblast or outer layer of the body; whilst the mouth is similarly formed by an infolding of the outer layer, and is later on placed in communication with the digestive system.

During the third day of incubation, certain highly important structures appear in the neck of the chick. Four clefts or slits (Fig. 97, A, *g*) are formed in the walls of the throat, these being named the *visceral* or *branchial clefts*. The upper edges of the clefts form thick folds, named the *branchial folds*, five folds existing to the four clefts, as the last cleft has its lower border thickened in addition to its upper edge. The significance of these clefts and folds will be hereafter alluded to; it may at present, however, be noted that all the clefts in the chick save the first are closed by the seventh day of incubation.

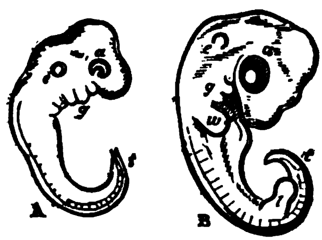


FIG. 97.—EMBRYO-VERTEBRATES.

The visceral "folds" contribute in an important fashion to the formation of the jaws and other structures belonging to the skull, the two hindermost folds disappearing in the chick, without leaving any traces of their existence. The limbs (Fig. 97, *w*, *l*) begin to be developed about the fourth day, and first appear as little buds projecting from a ridge—the "Wolffian ridge"—running round the young being from neck to tail at about its middle portion; but it is only about the fifth day that the distinctive characters of the limbs can be discerned. By the tenth day, however, the wings and feet, in all their characteristic structure, may be distinguished. The skull dates its history from the fifth day; and only during the succeeding day may the bird-type of the chick be perceived in the characters of wings, feet, digestive system, and other structures—so remarkably alike are the developing young of higher Vertebrates in their earlier stages of development. Meanwhile—as early, indeed, as the third day of life—the lungs have been formed as little pocket-like growths from the throat; and even before hatching, the chick begins to use its breathing organs. With fully formed parts, and perfectly equipped for the new existence which lies before it, the chick duly breaks the shell with its armed beak, and, throwing off the shrivelled remnants of organs once useful in its earlier stages, enters upon the characteristic life of its species.

If the development of a quadruped were traced, or the stages of man's physical progress in early life reported upon, much the same course of development as that described in the case of the chick would be chronicled. We should see segmentation of the quadruped-germ (Fig. 93, A, B, C, D), as in the lancelet; we should note the formation of a blastoderm and its three layers, of a primitive groove, of a notochord (Fig. 94, *ch*), of three brain-vesicles (Fig. 96, *fb*, *mb*. *hb*), of visceral or branchial clefts (Fig. 97, *g*), and of other structures similar to those of the chick. Only in the latest stages, should we be able to trace the appearance of the higher features of the quadruped or mammal as distinguished from those of the bird. Human development, so far as has been traced, runs parallel with that of lower forms of life, and exhibits the "morula" stage (Fig. 93, D) equally with the sponge (Fig. 87, 3), sea-squirt (Fig. 89, 3), or lancelet (Fig. 92, 3). Man's development is in truth but an epitome—condensed and modified, it may be, but still a recapitulation—of that of lower forms of life. Thus it is no mere supposition, but a weighty physiological fact, that through flitting and successive stages, which exactly repeat and represent permanent forms in lower life, man finally attains to be the "paragon of animals." And thus, also, the community of type and general structure which man shares with the lowest fish is demonstrated anew by the marvellous history of the manner in which that type is evolved, alike in its lower and higher phases.

The marshalling of facts to form generalisations, and the stringing of these facts upon the thread of a connected history, is a duty which lies next to hand in treating of development and the lessons it is calculated to teach. Let us, in the first place, try to discover the place and import of Harvey's teachings concerning development, as compared with those of succeeding investigators and theories. There can be no question that the researches of the nineteenth century have but confirmed and enlarged the observations of Harvey in the seventeenth. "Epigenesis" is seen to be the method of nature in developing the animal form with that "admirable and incomprehensible artifice" which Harvey so justly admired. From the primitive and undifferentiated protoplasm of the egg, modern embryology beholds the formation of the chick in a fashion strictly corresponding in all essential details to that outlined by the genius of Harvey. Compared with the views of Malpighi—holding that the egg contained a miniature chick, and that development was merely an unfolding or expansion of already formed parts—Harvey's description and theory of development stand forth in marked contrast in respect of their thorough correspondence with the fruits of modern research. Bonnet's theory of the "evolution," through the supply of nutrition, of an already formed chick contained in the egg, meets a like fate to the opinion of Malpighi; whilst his doctrine of "emboîtement"—crediting each germ with being the repository of all future germs—when taken literally, shares a like fate with his ideas regarding the evolution of the single animal form. As supplementing the ideas of Harvey by direct observation, we note the philosophic nature of the views of Wolff, through whose researches the foundations of modern embryology may be regarded as having been laid. The line of research leading from Wolff and Pander to the present day may be held to represent merely the direct continuation of the "Exercitations" of Harvey, whose "philosophising" has thus led to results of which its sage founder, with all his perspicuity, could have had no warning or idea.

The details of the studies in development outlined in this chapter must now be briefly summed up; whilst a glance at their bearings upon and teachings regarding evolution may form a fitting conclusion to the present stage of our studies. Firstly, then, it is noteworthy that the germ or ovum of all animals—excepting the very lowest, or *Protozoa*—appears as a protoplasmic mass, which exhibits all the characters of the microscopic body known as a "cell" (Figs. 87, 89, 92). In the lowest animals just named, the difficulty of distinguishing their germs, and indeed their entire developmental history, arises in great part from their ill-defined nature, and from the marvellous analogies and likenesses they present to their lower plant-neighbours. In the "biological no-man's-land" where the lowest animals and lowest plants meet in a confusing identity of form and function, distinctness of germ-elements may neither be expected nor found. But it is at the same time noteworthy that even in this lowest group of the animal series the observed phenomena of development occasionally present a singular resemblance to the primary process about to be alluded to, and already named segmentation; such resemblance being inexplicable save on the supposition that in these lowest forms the development of the higher is foreshadowed in dim outline.

Take as an example the development of *Magosphæra* (Fig. 98, 1), a low form of marine animalcule found living on the Norwegian coast by Haeckel. It resembles the familiar animalcule known as the Amœba; but during the development of new beings the Magosphæra assumes a spherical form (2), within which a nucleus (*a*) and nucleolus (*b*) give it the appearance of a veritable egg (compare Fig. 87, 1). Next in order succeeds a process remarkably like that known as "segmentation" in the eggs of higher animals. In the course of this process the Magosphæra divides (3, 4, 5), until a stage resembling the "mulberry stage," or *morula* (6), is attained. Thereafter the outer surface becomes ciliated, and, liberated from its investment, the Magosphæra swims freely (7) in the sea. Soon this free-swimming sphere breaks up into detached fragments of protoplasm, at first ciliated (8), but finally assuming (9) the adult Magosphæra form (1). In the well-defined groups of the animal world, ranging from the zoophytes, corals, and their neighbours (*Cœlenterate* animals), up to Vertebrates, including man himself, we are presented with a marvellous likeness and an undoubted correspondence in the form and nature of the germ, and of the processes in virtue of which that germ is started on its developmental journey.

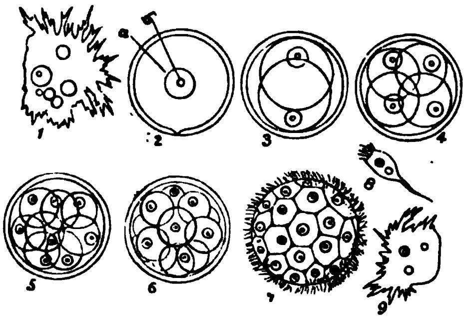


FIG. 98.—DEVELOPMENT OF A PROTOZOÖN.

Next in order, we note the occurrence, in the developing eggs of all animals, of that process to which the name *segmentation* has been given. We have seen that the germ or egg of the sponge, equally with that of the sea-squirt, lancelet, chick, and also with that of Mammalia, or quadrupeds, exhibits this process of division. The egg, at first single-celled, becomes in this way many-celled; and the variations observable in the process itself are but insignificant when contrasted with the extraordinary uniformity in the broad outlines thus exhibited by the eggs of all animals in their first stages, and in the changes preparatory to the outlining of the future form. But the similarity between the development of widely different animals ends not thus. If the process of segmentation is universal, the *morula* or "mulberry stage," in which that process culminates, is seen to be no less uniform and unvarying in its occurrence. Even among the Protozoa, as we have already remarked, we may perceive stages (Fig. 98, 6) in development which imitate the "mulberry mass" of higher forms. We have already traced the occurrence of this stage in the sponge and in the other life-histories described in this chapter; whilst a wider survey of the animal world would serve to show that in the early history of every group the "mulberry stage" is to be witnessed, as the first prominent landmark or halting-place on the journey of life. The egg of such an animal as a "Tardigrade" or Bear-animalcule—minute organisms allied to the mites, and found in the gutters of house-tops—thus exhibits in its development stages of a nature essentially similar to those seen in the history of both lower and higher forms of animal life. The egg itself (Fig. 99, 1) exhibits a structure comparable with that of all other germs. In its development the germ not only passes through the stages of segmentation (2, 3) already familiar to us in the sponges, sea-squirts, and vertebrates, but also arrives in due course at the mulberry epoch (4), or *morula*, whence the special features of the Tardigrades are specialised. How perfectly these details in the animalcule correspond with the stages in the development of the vertebrates or highest animals, is a fact which may be best appreciated by the comparison of the segmentation of the egg of a vertebrate animal depicted in Fig. 100, from its commencing development (1) to the attainment of the mulberry stage (5); whilst that of the frog (Fig. 101) exhibits essentially the same phases as the developing germ of bird or mammal. With

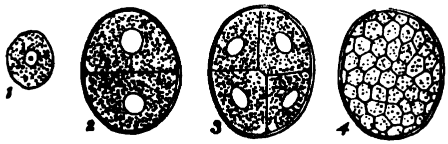


FIG. 99.—DEVELOPMENT OF BEAR-ANIMALCULE.

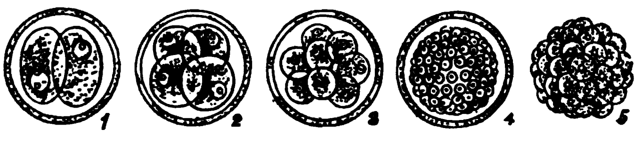


FIG. 100.—SEGMENTATION OF VERTEBRATE EGG.

Professor Allen Thomson we may therefore hold that "the occurrence of segmentation and the regularity of its phenomena are so constant, that we may regard it as one of the best established series of facts in organic nature."

But the further stages in development of different animals run parallel beyond the "mulberry stage" of progress. The morula, as we have seen, becomes a "planula"—a stage we saw distinctly in the sponge (Fig. 87, 4), and which is repeated with but little variation in the development even of the highest animals. Thus the "planula" appears to be well-nigh as universal in its occurrence as the "morula." But we saw that the planula in due course became the bag-shaped structure named *gastrula* (Figs. 87, 5; 89, 4; and 92, 4). The wall of the planula is pushed in upon itself on one side, a central cavity being thus formed, bounded by a double wall, and communicating with the outer world by the mouth. Such is the "gastrula"; and in its composition we are able to discern the two primitive layers, named, as we have seen, ectoderm (*ec*) and endoderm (*en*), or *epiblast* and *hypoblast*.

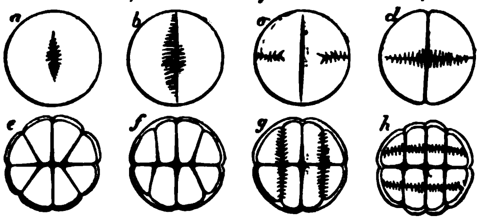


FIG. 101.—SEGMENTATION OF FROG'S EGG.

A third layer, the *mesoblast*, makes its appearance between these two primary membranes, and from these three layers, as we have already seen, all the structures of the future animal are in due course developed. It seems perfectly certain, then, that if the mulberry stage constitutes a first landmark in the development of the animal kingdom at large, no less does the "gastrula-stage" form a second resting-place in the track of life. Since, as Haeckel and other embryologists have shown us (Fig. 102), the gastrula stage of development (with its primitive mouth [*m*], body-cavity or stomach [*i*], and double layers [*ec* and *en*]) occurs equally in the zoophyte (5) and worm (1); is as typical of the star-fish (2) as of the crustacean (3); and aids as materially in the formation of the snail (4) as in the development of the vertebrate (6). After its "gastrula-stage," each animal form may

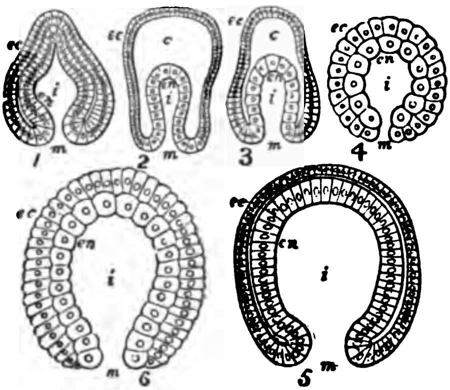


FIG. 102.—GASTRULAS OF VARIOUS ANIMALS.

be said to assume the special features of the group to which it belongs. At this point the vertebrate will pass towards its own sub-kingdom, and develop in due time the special features of the fish, the frog, the reptile, the bird, or the quadruped. Hence, as from a common point whence numerous ways and paths diverge, each organism will elaborate or develop its "gastrula" germ into a frame more or less complicated, and into belongings and structures suiting its rank in the great kingdom of animal life. From such a standpoint we may discern, more clearly perhaps than at any other stage of our researches, the justice of the comparison which symbolises the animal world and its origin by the figure of a tree, whose divergent branches bear at their extremities the apparently distinct and specialised groups of animals, but whose stem and trunk from which these branches spring, no less powerfully represents the common origin and uniform development of its varied parts.

That the evolutionist's case for the common origin and production by descent of the forms of animal life is strengthened and supported by the facts of development, is a statement which can admit of no question in the eyes of those who fairly face the facts, and who logically, and without bias or prepossession, construe their meaning. On any other supposition than that of the common origin and subsequent specialisation of the varied forms of animal life, the fact that a sponge, a sea-squirt, and a lancelet pass through essentially similar stages of development, presents itself simply as an inexplicable mystery. Community of development betokens community of origin; otherwise the facts of nature must present themselves as absurdities admitting of no logical construction whatever. Why a vertebrate animal in its earlier history should resemble a sponge or sea-squirt is a query simply unanswerable, save on the hypothesis that vertebrate ancestry was at one period transmitted through forms of which the sponges and sea-squirts are the existent and it may be the altered representatives. The development of an animal thus reasonably stands before us, in the newer interpretation of evolution, as a veritable panorama of its descent. Often, according to Darwin's already quoted remark, the series of pictures may here and there be obscured.

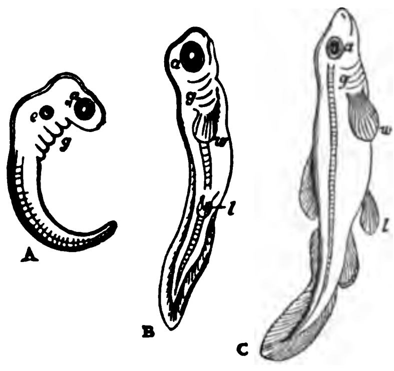


FIG. 103.—DEVELOPMENT OF A FISH.

The continuity of the shifting views may be interrupted by the extinction of stages through the influence of external conditions or of unknown causes. But in most cases, the outlines remain clearly and fairly drawn, and afford us a glimpse into the order of nature, not only more astonishing, but also more convincing in its teachings, than the views obtained of the world of life from any other standpoint.

There yet remain for consideration one or two important points suggested by the details of animal development—these latter points bearing as intimately, perhaps, on the argument for evolution as the grand facts of development themselves. First in order, it behoves us to note the interesting facts concerning the branchial arches and gill-clefts of vertebrate animals, already noticed, and the conclusions to which the observation of these facts eventually leads.

The branchial or gill clefts were remarked as being developed in the neck or throat of the chick (Fig. 97, *g*) about the third day of incubation. The part subsequently played by certain of these structures in the formation of the jaws was duly noted; the remaining clefts and folds disappearing in due course, and leaving no trace of their existence behind. Shortly stated, the history of these gill-openings shows us that they are of universal occurrence in the development of the vertebrate group of animals. They appear in the fish (Fig. 103 A, *g*) and in the bird (Fig. 97, *g*). They are developed as persistently in man's early history as in the development of the frog or reptile. No more convincing proof of the community of development in this respect could be adduced than the comparison of the early embryos of different vertebrate animals. In Figs. 97, 103, and 104 such comparisons have been made. The gill-arches are there seen to be as clearly the natural heritage of

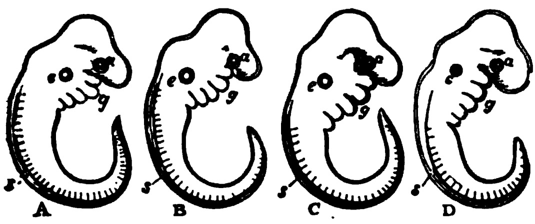


FIG. 104.—EMBRYOS OF QUADRUPEDS.
(A) Pig; (B) Calf; (C) Rabbit; (D) Man.

man (Fig. 104, D) as of the rabbit (C), calf (B), and pig (A); whilst they are as typically represented in the chick (Fig. 97, *g*) and fish (Fig. 103, *g*). In the fish and in some newt-like animals, the visceral clefts and arches become permanent features of their adult life, and are associated with the "gills" or breathing organs.

But reptiles, birds, and quadrupeds are lung-breathers, and possess gills at no period of their life. Why, then, it may be asked, should they invariably develop in their early life gill-arches and gill-clefts which bear no relation to the wants of their adult existence? The gill-arches of reptiles, birds, and mammals never develop gills; and even the gills and gill-clefts of tadpoles (depicted in Fig. 105, *g*) disappear when these animals become adult toads, frogs, and newts. Why, then, it may be repeated, does this seeming irrationality and useless expenditure of creative power in nature exist?

The true and only answer to such a pertinent query is, that the gills and gill-arches of higher Vertebrates bear reference to a former condition of matters. They relate to anterior stages of vertebrate existence, when the ancestors of lung-breathing animals were represented by gill-bearing and aquatic forms. Gill-arches and gill-slits

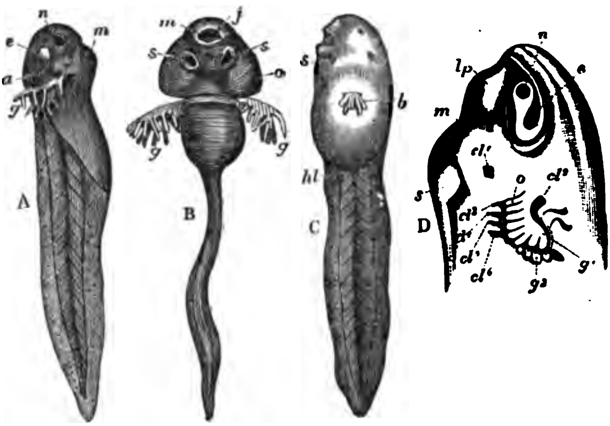


FIG. 105.—TADPOLES OF FROG.

thus appear as a true legacy and inheritance from an aquatic ancestry. In the higher Vertebrata the first gill-opening becomes converted into structures and parts connected with the ear. The remaining clefts disappear, whilst the gill-arches themselves contribute to form the tongue-bone (hyoid bone) and the small bones or vesicles of the internal ear. Only on the theory of descent with modification can we rationally explain the presence of now useless structures such as the gill-arches and gill-clefts of lung-breathing Vertebrates. On this principle, "we may cease marvelling," says Darwin, "at the embryo of an air-breathing mammal or bird having branchial slits and arteries running in loops, like those of a fish which has to breathe the air dissolved in water by the aid of well-developed branchiæ."

The method of disappearance of the gills and their arches is as reasonably detailed, when Darwin states that, "in order to understand the existence of rudimentary organs, we have only to suppose that a former progenitor possessed the parts in question in a perfect state, and that under changed habits of life they became greatly reduced, either from simple disuse, or through the natural selection of those individuals which were least encumbered with a superfluous part, aided by the other means previously indicated."

Another fact of interest, derived from our studies in development, relates to the position of the sea-squirt larva and of the lancelet as together constituting "links" which bridge the gulf between the Invertebrates and their higher backboned neighbours the vertebrate animals. Only when we think of the apparently great gulf fixed between the fishes as the lowest Vertebrates and all invertebrate forms, can we realise the gain to evolution of the knowledge which shows how the development of the sea-squirt and that of the lowest Vertebrate run in parallel lines. Such a correspondence in development, and the discovery of the possession by sea-squirts of the "notochord"—long thought to be the exclusive possession of the Vertebrates—constitute together a veritable tower of strength for the evolutionist, whence he may survey a formidable gap supplied, and a "missing link" satisfactorily brought to light.

It should lastly be noted that the facts brought to light by a study of the early stages in the development of animals, may be regarded as being thoroughly in favour of the theory of Evolution. Professor Allen Thomson, in his presidential address to the British Association (1877), stated the latter fact forcibly when he said, "I consider it impossible, therefore, for any one to be a faithful student of embryology, in the present state of science, without at the same time becoming an evolutionist." These are weighty words, but they are fully justified by the circumstances of the case to which they apply. And no less apt are the terms in which the same authority in matters embryological further alludes to the support received by evolution from daily life histories of living beings. "If," says Professor Thomson, "we admit the progressive nature of the changes of development, their similarity in different groups, and their common characters in all animals—nay, even, in some respects, in both plants and animals—we can scarcely refuse to recognise the possibility of continuous derivation in the history of their origin."

X.

THE EVIDENCE FROM DEVELOPMENT (continued).

II.—THE LIFE-HISTORIES OF STAR-FISHES AND CRUSTACEANS.

ALLUSION has already been made in the preceding chapter to that most fundamental proposition of modern biology which maintains that "community in development reveals community of descent." It has also been shown at length that, in the eyes of modern naturalists, the development of an animal or plant is regarded as affording a clue to the manner of its evolution or descent from pre-existing forms. The formation of a living being to-day, in other words, repeats for us the formation of its race and species in time past. So that, once again to quote Darwin's words, "we can understand how it is that, in the eyes of most naturalists, the structure of the embryo is even more important for classification than that of the adult." Or, again, "embryology (or development) rises greatly in interest when we look at the embryo as a picture, more or less obscured, of the progenitor, either in its adult or larval state, of all the members of the same great class."

Second to none in interest, in the eyes of modern biologists, are the phenomena presented to them in the formation of the animal or the plant frame. In former years the mystery of development was great indeed. There could be offered in the past decade of biology no reason—appealing sufficiently to the rational intellect as explanatory of the events in question—why a frog in its development should appear first as a gill-breathing fish, later on as a tailed newt-like creature, and ultimately as a tailless lung-breathing amphibian. Nor could natural historians in the past venture to account in more lucid fashion for the curious changes which a butterfly or beetle undergoes in its progress from the days of its youth towards the adult form, and from the stage of the crawling grub, through that of the quiescent chrysalis, to the full-fledged "imago" with its wings. Kirby and Spence summed up and dismissed such matters in a manner—unfortunately for the free play of intellectual vigour, not quite extinct in these latter days—which said much, perhaps, for faith, but little or nothing for reason and science. These famous entomologists held that insects passed through a metamorphosis because "such is the will of the Creator;" and they supplement this "confession of faith" with an attempt at a scientific explanation by the further assertion that, insects being voracious in their feeding habits, especially in earlier life, perform an important function in the economy of nature in that they remove from the earth's surface "superabundant and decaying animal and vegetable matter." A further reason for this providential arrangement was given in the fact that, as "unusual powers of multiplication" were indispensable for recruiting the ranks of the insect scavengers, and as nutrition and reproduction are incompatible functions, the removal of decaying matter during the youthful stages of the insect's life was to be regarded as a convenient subdivision of its labours, seeing that its adult existence is spent in the work of reproducing its race. But it might easily be shown that, whilst a goodly number of larval insects do feed upon carrion, a large proportion of the class does not exhibit any such habit; and it might reasonably enough be maintained that the argument of Kirby and Spence is open to the serious objection that, in its character, it tends to illustrate the *post hoc ergo propter hoc* fallacy—Decaying matter exists, therefore insects were designed to pass through a metamorphosis, and were gifted with voracity of disposition that they might remove the said matter from the earth's surface—a proposition vitiated in its exactitude by the fact just mentioned that many insects do not eat such matter; and also by the further facts that many do not undergo a metamorphosis at all; that many voracious caterpillars, instead of eating decaying matter, destroy our trees and flowers. It might also be added that many of nature's scavengers of higher and lower rank than the insects, do not pass through a series of changes in development, but grow, nourish themselves in the exercise of their sanitary work, and likewise, at the same time, and as adult forms, reproduce their species and continue their race in time. Clearly, then, the explanation of Kirby and Spence affords no satisfaction to the contemplative mind in the natural anxiety and desire to discover the causes of things. At its very best, such explanation leaves "the reason why" untouched; and conversely, it can well be understood how any other system of thought, which presents a more satisfactory method of accounting for the facts in question, should find ready acceptance as expanding and enlarging the thoughts of men.

In the previous chapter we discussed the meaning of the remarkable likenesses which can be readily proved, as matters of fact and observation, to exist between the early stages in the development of very different animals. A sponge, a sea-squirt, a lancelet, and even higher animals still, appear in the first beginnings of their existence to pursue a remarkably similar course. Each form parts company with its fellows at a given stage on the way of development, and thereafter passes by the special pathway of its race towards the adult and perfect stage. Von Baër's axiom that development proceeds from the general to the special, thus declares a great truth of nature. Modern biology appears provided with a host of witnesses to the truth of that axiom, and supplies a reason for the likeness by assuming similarity of descent from lower life as the explanation of those common and general beginnings from which the special and varied forms of animals and plants are evolved every hour around us. The axiom that the development of the individual (*ontogenesis*) is the rapid shifting or panoramic recapitulation of the development of the species (*phylogenesis*), is now regarded in biology as the keynote of the whole study of animal and plant formation. If we find, for instance, that the frog in its development is firstly a fish, then a tailed amphibian or newt, and, last of all, a tailless, air-breathing frog, we see in such a panoramic succession of changes—constituting the development of the individual—the evolution and development of the frog race. We read such a history as showing us clearly enough that the frogs have been evolved from some ancient fish-stock, that this fish ancestor became through succeeding modifications a tailed, newt-like amphibian, and finally, that the newt in turn became the higher frog. Most reasonable is the supposition and belief that, if the living hosts have descended from common ancestors, the appearance of ancestral features in their development is a most natural expectation and a highly natural law of life. That transmission from parent to offspring of hereditary features, so familiar to us in human existence—the reproduction of family features by the successive descendants of the family stock—is, in truth, but the repetition in higher life of the likenesses to its ancient ancestry we see in the developing frog. On such grounds, we may attempt successfully to explain the mysteries of development; and on such a principle, we may note in passing, it is easy to see how important a guide to the classification and arrangement of living beings their development affords. If those animals which are descended from a common ancestry resemble each other in their development, such resemblances may be held to represent the truest of those blood relationships which it is the business and aim of classification to express.

The chronicle of the development of animal life is, however, not completed when the earliest changes seen in the formation of the animal frames have been noted. Long after the common and earliest stages, described in the last chapter, have been completed, there may be produced before us marvellous resemblances and likenesses between animals which, when adult, would seem to possess no community either of origin or of other relationship. It is to these later changes in the animal form that we now purpose to direct attention. The history of those changes which more immediately precede the assumption of adult life, affords as valuable evidence of the evolution of species, as does the chronicle of the very beginnings of existence. It is only needful to point out at the commencement of such a study, that admittedly the panoramic views of evolution we are about to discuss frequently present breaks and gaps in their succession. The expanding canvas of life here and there exhibits a blank surface, due to the part erasure of the picture which, we believe, formerly existed thereon.

There exists a second principle in nature and evolution, of equal importance to *heredity* or that in virtue of which the likeness of the parent or ancestors is transmitted to the offspring or descendants. This second principle is that of "modification" by *adaptation* to surrounding or varying conditions. The living being is a plastic unit, capable of being affected and impressed in various, and often undetermined fashions, by the forces of the world in which it lives. Such external conditions—heat and cold, food, habitat, and a host of other circumstances—influence its development in the present, as unquestionably in the past they have modified the history of its race. In truth, the germ-idea of evolution is that of progressive change and alteration induced by the great factors—internal or innate, hereditary and vital forces, and the external or outside circumstances of life. To the operation and influence, then, of surroundings, acting variously upon different natures and organisms, we rightly ascribe the deletion of stages we would naturally expect to meet with in that recapitulation of the animal evolution exhibited in its development. As the geological record, through its imperfections—due to the metamorphism and destruction of fossil-bearing rocks—causes grievous gaps in the history of past life on the earth, so the history and development of the life of to-day shows its blanks and imperfections likewise—these blanks caused chiefly, we believe, by the varying outward conditions under which the development of the race was carried out. Thus, if the main outlines of the development of the frog-race be plainly delineated, the pictures likewise may exhibit here but the dimmest possible contour, and may there show a blank. The original fish-ancestor of the race must be sought for amid the fossils—possibly it may never come to light at all. The successive stages whereby the tailed newt became the frog, are barely outlined in the animal world of to-day, and are here and there wanting altogether. But the finger-posts exist nevertheless, and they guide our mental way satisfactorily enough, so long as we trust to their indications. Even though we have to wade through the high tides of difficulty and dimness of knowledge which obscure the intervening ground, we may walk with confidence in that sober path which is founded upon the reason that is attainable.

As Huxley pertinently remarks in a recent manual of zoological instruction: "In practice, however, the reconstruction of the pedigree of a group from the developmental history of its existing members is fraught with difficulties. It is highly probable that the series of developmental stages of the individual organism never presents more than an abbreviated and condensed summary of ancestral conditions; while this summary is often strangely modified by variation and adaptation to conditions; and it must be confessed that, in most cases, we can do little better than guess what is genuine recapitulation of ancestral forms, and what is the effect of comparatively late adaptation. The only perfectly safe foundation for the doctrine of Evolution," continues Huxley, "lies in the historical, or rather archæological, evidence that particular organisms have arisen by the gradual modification of their predecessors, which is furnished by fossil remains. That evidence is daily increasing in amount and in weight; and it is to be hoped that the comparison of the actual pedigree of these organisms with the phenomena of their development may furnish some criterion by which the validity of phylogenetic conclusions (or race-development), deduced from the facts of embryology alone, may be satisfactorily tested."

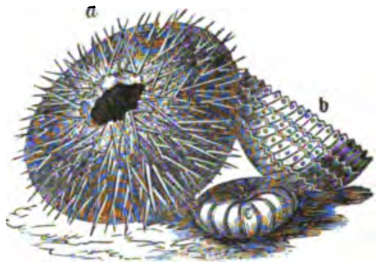


FIG. 106.—SEA-URCHINS.

A survey of some typical groups of animals in relation to their development will provide us with satisfactory means of judging how far and how plainly the history of the individual repeats that of its race. Turning firstly to some fields of lower life, we may select the class (*Echinodermata*) represented by the Starfishes (Fig. 107), Sea-urchins (Fig. 106), Sea-lilies (or Crinoids) (Fig. 109), and Sea-cucumbers (Fig. 108), as a starting-point for our inquiries. There is little need that a list of zoological characters should be enumerated by way of impressing the idea of the varied appearance of the animals just mentioned. But it may be remarked that, firstly, they all exhibit

FIG. 107.—STARFISHES.

a fundamental likeness in structure, beneath diversity of form; and, secondly, that such general or fundamental agreement is seen in the management of their internal organs—digestive system, heart, nervous system, &c., and especially in what zoologists term their "radial symmetry"—that is, their generally rounded form arising from their bodily elements, so to speak, being moulded around a central point (Fig. 107), the mouth. However like these animals may be in general structure, they, at the same time, present us with very diverse forms. On the hypothesis of special creation, nothing could appear more rational than the idea that dissimilarity of form was due to the separate circumstances of their creation. But such an idea overlooks at the same time their general likeness in structure; and it certainly takes no account and gives no explanation of the singular uniformity and resemblances presented by these animals in early life. The general likeness in question, in fact, simply reiterates and strengthens the evidence and conclusions that the varied tribes of Starfishes, Sea-urchins, Crinoids, and Sea-cucumbers have arisen from a common ancestry. Let the history of their development prove the truth and validity of this conclusion.

FIG. 108.—SEA-CUCUMBERS.

Selecting a Starfish as the most familiar form of the class, we find its early development to exhibit those stages of egg-segmentation common to the developing ovum of all animals, and which have been already discussed. But the special features of Starfish-development soon begin to show themselves in the production of a worm-like organism, utterly different from the Starfish-form, and which swims freely in the sea by means of the delicate *cilia* or vibratile processes with which the sides of its body are provided. This larva possesses a digestive system, a system of water-tubes and other structures; and it would thus seem as if from the egg of the Starfish a wholly different progeny was destined to arise. So unlike is the young organism to the parent, that when first discovered, it was described by Sars in 1835 as a hitherto unknown form under the name of *Bipinnaria* (Fig. 110, A). In due time, however, a secondary formation begins to appear within this latter body (Fig.

110, B, *a b*), and the curious spectacle is soon beheld of the form of the young Starfish growing within and absorbing the materials of which the Bipinnaria-body is composed. So that when development is completed, the Bipinnaria's substance has become appropriated by the new and secondary formation, which latter duly appears as the true Starfish, destined, after ordinary growth, to assume the adult form.

The study of a Sea-urchin's early life-history reveals a striking similarity to the development of a Starfish. The embryo Sea-urchin, "in escaping from the egg" (Fig. 111, A B), says Agassiz, "resembles a Starfish embryo, and it would greatly puzzle any one to perceive any difference between them. The formation of the stomach, of the œsophagus (or gullet), of the intestine, and of the water-tubes takes place in exactly the same manner as in the Starfish, the time only at which these different organs are differentiated not being the same." But at a later stage the young Sea-urchin develops a different phase and form from those of the Starfish. It appears as a curious body, shaped somewhat after the fashion of a painter's easel and formerly named *Pluteus* (Fig. 111, C), under the idea that it represented an adult and distinct being. Within this Pluteus, a skeleton of limy rods is developed, and a digestive system is also formed. Then succeed the final stages in development. The body of the Pluteus is absorbed by the future Sea-urchin (Fig. 111, D), which, as in the Starfish, is formed within and from the substance of this larva—with this difference, that a portion of the Pluteus is generally cast off as useless material, whereas in the Starfish the whole larva was utilised in the manufacture of the perfect form. There exists a second group of Starfishes, including the

FIG. 109.—CRINOID.

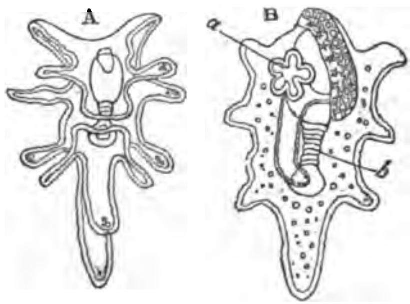


FIG. 110.—LARVÆ OF STARFISH.

Brittle-stars and Sand-stars (Fig. 107, 5), and exhibiting certain differences in structure from the common Starfishes of our sea-beaches. In their development these Sand-stars and their neighbours approach very nearly indeed to that of the Sea-urchins. Their larva is also a "Pluteus," and possesses a limy skeleton; and it is singular to find that forms so divergent in character as the Sand-starfishes and Sea-urchins should thus resemble each other in development.

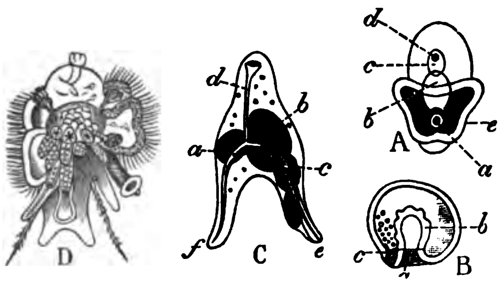


Fig. 111.—Development of Sea-urchin.

The interesting group of the Crinoids, or Sea-lilies (Fig. 109)—well known in a fossil state under the name of "Encrinites"—presents us with beings that may best be described as Starfishes borne on stalks. There exists, however, a well-known free Crinoid in the shape of the *Comatula* (*Antedon*) *rosacea*, or the Rosy Feather-star of our coasts (Fig. 112); this form appearing in its adult condition as a free, unattached "Starfish" (Fig. 112, *a*), but indubitably proving its Crinoid nature, in that it spends the early part of its existence in a stalked condition (*b*), resembling the permanent state of its neighbour Sea-lilies (Fig. 109). Now, in the development of the Crinoids, we meet with an oval, free-swimming larva, within which a digestive system duly appears. This organism

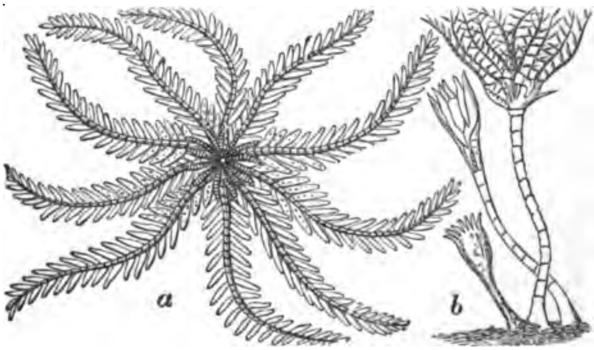


Fig. 112.—Rosy Feather-star and Young.

in due course attaches itself by a stalk, and the future Crinoid is developed within this larva; a new mouth and digestive apparatus are produced, and the adult stalked form is assumed. In the Rosy Feather-star such development, with its characteristic modifications, is well seen. Here we first see the oval larva, with its four bands of cilia (Fig. 113, A), and a tuft of these organs at the posterior extremity. Then traces of the future adult (B) appear within this body. As development proceeds, the cup or body of the Crinoid is formed, the tentacles or arms bud forth, and the young Feather-star, already stalked (C), appears in the likeness of a true Crinoid. Here development might be thought to have well-nigh attained its limit. So thought the discoverer of this little stalked form, when it was announced that in the Cove of Cork a *rara avis* in the shape of a British Stalked Crinoid (duly named *Pentacrinus Europæus*) (Fig. 112, *b*) had been found. But years afterwards, the little Pentacrinus was seen to leave its stalk, and to appear before the eyes of zoologists in the guise of an old familiar friend—the Rosy Feather-star (Fig. 112, *a*) of the coasts. Thus we discover, firstly, that Crinoids resemble their neighbours the Sea-urchins and Starfishes in the essential details of their development; and we discover, secondly, in the case of the Rosy Feather-star, a further development of the Crinoid race, in that this latter organism has advanced to a free-living stage. Also noteworthy is the fact, that when existing in its rooted and stalked stage, the Rosy Feather-star closely resembles the ordinary fixed Crinoids, and perhaps bears a still closer likeness to certain fossil members of the group.

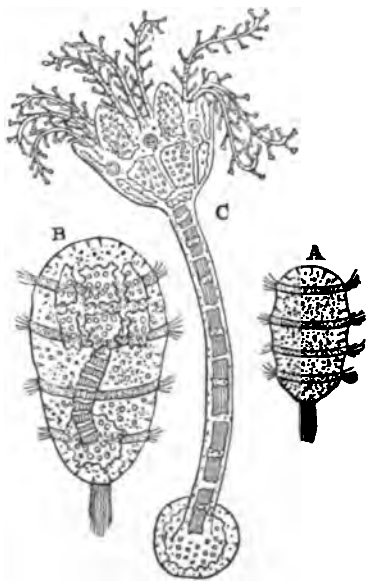


FIG. 113.—DEVELOPMENT OF CRINOID.

The last class of Echinoderms demanding attention is that of the Holothurians, or Sea-cucumbers (Fig. 108), found around our own coasts, but developed typically as the Trepangs and Bêches-de-Mer of tropic seas, and in marketable form as the delicacies of the Chinese. A Sea-cucumber presents us with an elongated body, bearing a tuft of feathery tentacles at the mouth-extremity, and moving by aid of tubular "feet," similar to those of the Starfishes and their neighbours. Here development resembles that of the Starfishes, and begins (Fig. 114, A B) with the production of an oval, ciliated body, which soon acquires a digestive system. The young Sea-cucumber, in the guise of what is called its "Auricularia-stage" (Fig. 114, C), presents a cylindrical figure, with four or five bands of cilia, and bears ear-like processes—hence its name. Before this larva is fully formed, the future Sea-cucumber commences its existence as a growth existing near the larval stomach. The tentacles of

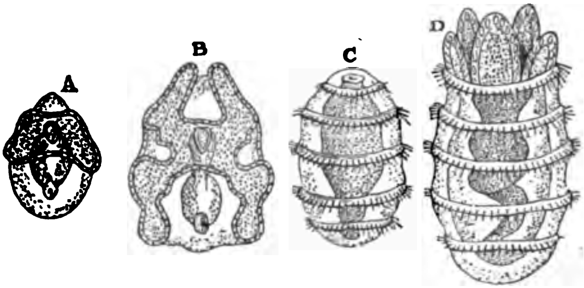


FIG. 114.—DEVELOPMENT OF SEA-CUCUMBER.

the young Holothuria soon appear (D), the ear-like projections are absorbed, the Auricularia assumes a cylindrical form, and, becoming the "pupa," bears a striking resemblance to a worm. When the process of absorption proceeds to a further stage, the Auricularia wholly disappears; and as the new body which has been developed at its expense elongates, the young Sea-cucumber form is duly evolved.

Such is the course of development in the sea-urchins and their allies. The chronicle in question is well adapted to supplement the important considerations advanced at the commencement of this chapter. There is strikingly seen in the development of these animals, firstly, that broad resemblance in their earliest stages which augurs for a cómmon derivation, and which proves, what their adult structure teaches, that these organisms are simply so many modifications of a common plan. In each and all, the first larva gives origin to a second within itself, this second growth becoming the true and adult form; so that the first larva produces the new being, as it were by deputy. And whilst general similarity in development thus may be taken to mean community of origin, if it has any meaning at all, there remains illustrated to us the second principle involved in the study of development at large. The differences between the early forms of these various groups are readily enough explicable on the theory that adaptation and variation (acting through undetermined laws of life, or through the influence of outward conditions, or through both of these phases) have been at work, evolving, from the common larval type, the differences of form perceptible in their present-day development as well as in their adult structure. This principle of adaptation is perhaps best illustrated by those cases of "direct" development—seen in some species of Holothurians and Starfishes, &c.—in which the young appear in the likeness of the parental form without undergoing a metamorphosis or series of changes. In such a case, the obliteration of these changes has probably depended upon causes which at present we are unable to trace; the directly developed forms probably representing the later products of evolution. But it is needless to remark that, on the clear evidence afforded by the typical development of these animals generally, the theory of their common origin is in nowise affected by the elimination, here and there, of the ancestral features of the race. Perhaps the sea-cucumbers and starfishes represent the most typical and least altered cycles of development, whilst the sea-lilies and sea-urchins present us with the results of a more modified series of changes. But, theoretically, there is little difficulty in assuming that, could we look backwards in time with definite glance, we should expect to see the origin of our sea-stars and their allies in a stock which, if anything, approaches most nearly to the form of some primitive worm than to that of any other animal form. Such a primitive form is, perhaps, best outlined in the larva of the Sea-cucumber itself (Fig. 114, B C). Indeed, the evolution of the Echinoderms from some such worm-stock is one of the well-founded generalisations of modern zoology. There exist, it may be added, in the developmental history of the worms themselves, certain features which go far to support the idea of a far-back relationship with the sea-urchins and their neighbours—these latter forms being apparently removed very far from the worm-stock as they present themselves to our view in the forms of adult and perfect existence. There is a curious marine worm, named *Balanoglossus*, the larva of which, known as *Tornaria*, certainly approaches, of all other known forms, most nearly to the youthful starfishes, sea-cucumbers and their neighbours. Indeed, the young Balanoglossus has been described as intermediate between the young of Echinoderms and the larval forms of molluscs to be hereafter (Chapter XI.) described. Balanoglossus itself, is peculiar in possess-

FIG. 115.—CRAB.

ing gill-slits resembling those seen in the early life of all Vertebrates. There seems little reason to doubt that this curious animal is a survival of a once widely-represented type, which to-day exhibits decline and decay, whilst preserving for us the important characters of a common ancestor of several existing groups of animals.

Ranking above the sea-stars, in respect of generally higher organisation, we find a very numerous and varied assortment of animals known as the *Crustacea*. The etymology of this latter term might suffice to convey information respecting the typical representatives of the group, inasmuch as the presence of a hard crust or "shell" characterises the higher forms, as well as many lower members of this class. Such higher forms are the crabs (Fig. 115), lobsters, shrimps, prawns (Fig. 132), water-fleas (Fig. 116), and their neighbours, which possess a "shell"—although, as even a tyro in zoology knows, the "shell" of the crab is a widely different structure, in nature as it is in appearance, from the "shell" of the oyster or whelk. The crab's shell is periodically slipped off its body to admit of the animal's increase in size; whilst that of the mollusc—oyster, mussel, whelk, &c.—is a permanent structure, attached by muscles and other organic means to the animal's body, growing steadily as bones grow in ourselves, and forming, therefore, a much more important item of bodily belongings than does the Crustacean's covering. But apart from the nature of the "shell," the *Crustaceans*, as one may see in the jointed tail of the lobster or shrimp, are very differently planned, so to speak, from the Molluscs. They are "Articulate" or "jointed" animals, and naturally claim insects, centipedes, scorpions, spiders, *et hoc genus omne*, as their relatives and friends. Now, this great Crustacean class includes a very motley and varied series of beings. At its head, as we have seen, are the lobsters, crabs, shrimps, and prawns; its middle-classes are represented by the "water-fleas" (Fig. 116), whose name is legion; and its lower orders are the barnacles (Fig. 117), the sea-acorns, the Sacculinas (Fig. 118), and a host of allied creatures which certainly present us with the best examples of degradation in the animal kingdom, in that they exist for

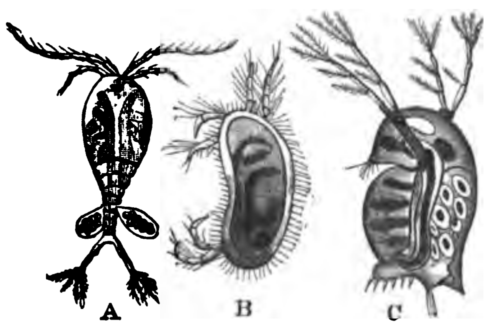


FIG. 116.—WATER-FLEAS.

the most part as footless, often as mouthless, and frequently as shapeless organisms, attaching themselves to fishes and to other Crustaceans, and living the low existence pertaining to the parasite whether of higher or lower grade. There seems no wider dissimilarity, for instance, between any two animals, than between the shrimp or prawn (Fig. 132) and the bag-like Sacculina (Fig. 118), which attaches itself to the bodies of crabs. There is apparently a wide distinction between the structure of a crab (Fig. 115) and a water-flea (Fig. 116), and still more between a barnacle (Fig. 117) and a prawn (Fig. 132). Yet in the classification of zoology these diverse beings are ranked as members of the same class; and development, as the great criterion of classifications, sanctions the arrangement. Let us endeavour to discover the grounds which warrant the assertion of such near relationship.

No fitter starting-point can be found than the development of the Barnacle (Fig. 117), which, attached to floating wood by its fleshy peduncle or stalk, enclosed within its shelly habitation, and sweeping the waters with its set of feathery plumes or "cirri," lives a life bordering nearly on the state of parasitism itself. From the egg of the barnacle—and after the preliminary stages of development which are common in greater or less degree to the personal evolution of all animals—comes forth a little creature (Fig. 119), so utterly unlike its parent that one might well feel disposed to reject the claims of the aphorism "like begets like," so universally expressive of the relation betwixt parent and progeny. The body of the young barnacle is triangular in shape; its anterior angles are protruded into horn-like processes; and it possesses a mouth and digestive system, a single median eye-spot, a forked tail, and three pairs of feet or limbs.

FIG. 117.—BARNACLES.

In this stage it is known as a *Nauplius*; and it may be well to keep the characters of this little organism in mind, since we shall find them to reappear in the progeny of animals of diverse nature from our Barnacle. The course of Nauplius-life lies in the direction of frequent moults, and by-and-by it assumes, after a special change of skin, the form of the "pupa"-barnacle (Fig. 120, B). It passes, in other words, from the days of its infancy to the days of its youth. As the "pupa," its body is enclosed in a bivalve shell or "carapace." Two compound eyes replace the single organ of vision of the Nauplius-stage; the first pair of legs (Fig. 120, B *a*) have become enlarged, and appear as antennæ or feelers provided each with a sucker; whilst behind the mouth six pairs of "cirri," or small hair-like limbs (*f*), are developed. The mouth appears to become abortive in this stage, in which the resemblance of the young Barnacle to a Water-flea such as *Daphnia* (Fig. 116, C) or *Cypris* (B) is sufficiently striking. Darwin remarks, that in the Nauplius-stage the young barnacles feed actively and increase in size; whilst in the second stage, their function is "to search out by their well-developed organs of sense, and to reach by their active powers of swimming, a proper place on which to become attached and to undergo their final metamorphosis."

The concluding phases in barnacle-history are not difficult to trace. The body of the young barnacle becomes somewhat flattened and compressed, and, as Darwin remarks, resembles in its shape a mussel-shell or the water-flea known as *Cypris* (Fig. 116, B). The carapace or shell appears paramount in the final stages of development, the limbs and body being hidden and enclosed by the shell; and although jaws exist, these organs are covered by integument, and the organism is thus deprived of the power of nourishing itself. Certain remarkable glands now begin to be developed in the pupa-barnacle. These organs open by the so-called "cement-ducts," in the suckers of the well-developed first pair of appendages—the great feelers or antennæ (*a*) already mentioned. The pupa in due time seeks a location and resting-place, and adheres (Fig. 120, A) to its floating log, or to the side of the ship, by means of its feelers. Thereupon the cement glands pour out their secretion, which acts as a veritable "marine glue," defying the solvent action of the water, and fastening the barnacle head downwards to the place of attachment. Then the compound eyes disappear, leaving the future existence of the barnacle sightless. The characteristic limy formations or plates seen in the "shell" of the adult barnacle (Fig. 117) are developed. The six pairs of swimming feet become the plumes, "cirri," or "glass hand" of the barnacle, and by their incessant waving draw food particles into the mouth. With the production of the characteristic fleshy stalk or "peduncle" of the full-grown form—which grows from the front part of the body

FIG. 118.—SACCULINA.

—this curious history comes to an end. Barnacle-growth therefore exhibits as its stages, firstly, a free-swimming larva or "Nauplius" (Fig. 119), with its three pairs of legs or appendages; then a pupa with its bivalve shell, its large feelers, its two eyes, and its six pairs of swimming feet (Fig. 120, B); and finally the eyeless, stalked, and degraded adult stage, in which, to quote the words of authority, a barnacle appears as a crustacean, "fixed by its head, and kicking the food into its mouth with its legs."

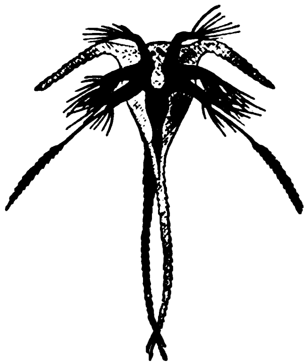


FIG. 119.—YOUNG OF BARNACLE.

From the crustacean array, we may next select an animal which, whilst it resembles the Barnacle in many of its features, and especially in development, is yet sufficiently distinct to lead towards forms presenting greater differences in the adult stage and yet exhibiting close identity in the early phases of existence. Such a form is the Sacculina (Fig. 118), a type of Crustaceans of the very lowest grade, which live an attached, rooted, and parasitic existence on

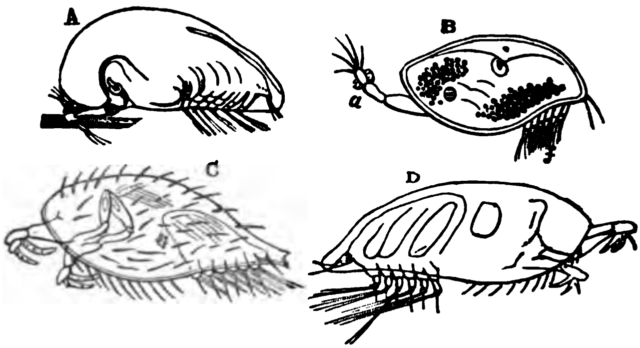


FIG. 120.—DEVELOPMENT OF BARNACLES, &c.

fishes or on other crustaceans. If a barnacle exhibits "retrograde development" or physiological backsliding, in that it appears to be a lower and more modified form when adult than when in the pupa-stage, the Sacculina and its neighbours exhibit a still more degraded condition. The organism just named, exists as a sausage-like bag attached to the bodies of hermit-crabs. There exist no traces of a mouth—or, as Fritz Müller remarks, "they lose all their limbs completely, and appear as sausage-like, sack-shaped, or discoidal excrescences of their host, filled with ova (or eggs); from the point of attachment closed tubes, ramified like roots (Fig. 118), sink into the interior of the host, twisting round its intestine, or becoming diffused among the sac-like tubes of its liver. The only manifestations of life which persist in these *non plus ultras* in the series of retrogressively metamorphosed crustacea, are powerful contractions of the roots, and an alternate expansion and contraction of the body, in consequence of which water flows into the brood-cavity and is again expelled through a wide orifice."

Now, the history of Sacculina-development clearly proves its relationship with other crustaceans. As an adult, a Sacculina might literally be anything in the way of animal organisation. It is a bag filled with eggs, and attached by roots to a hermit-crab. As such, its true nature is not recognisable by any of the deductions to be drawn from the ordinary facts of animal structure. Development, however, not only shows us its descent, but settles its place in the animal scale by declaring its affinities, not only with the Barnacles, but with other crustaceans. From each egg contained within the bag-like body, there is developed a little free-swimming creature (Fig. 121). This embryo possesses an oval body, ending in two short processes; three pairs of swimming feet are developed; a single eye may or may not be present; but we find in the young Sacculina a clear and unmistakable reproduction of the "Nauplius" (Fig. 119) of a Barnacle. No mouth or digestive system, however, exists in the youthful Sacculina, which shortly changes into the "pupa" state (Fig. 120, C). Here it closely resembles the *Cypris* water-flea (Fig. 116, B), whose development we shall also presently note. It possesses a shell folded down at the edges so as to enclose the body. The front pair of limbs, as in the Barnacle, become modified to form organs of attachment; the two remaining pairs of feet are cast off; and, as in the Barnacle, six pairs of forked swimming feet appear on the body behind, while the forked tail is also a characteristic feature of the young Sacculina. Then succeeds the stage of attachment. The front feet, or feelers, serve as means of fixation to the body of the crab-host. The remaining six pairs of feet are cast off; the roots are developed from the feelers, and the animal thus assumes the adult sac-like and degraded form. Thus a Sacculina and its parasitic neighbours closely resemble barnacles up to the pupa-stage. At this point the evolution—manifested in "degradation"—of the Sacculina intervenes, and the six pairs of feet, which in the Barnacles are converted into the "cirri" or "plumes,"

FIG. 121.—NAUPLIUS OF SACCULINA.

are cast aside as useless. The process of extreme modification for a life of parasitism effectually moulds the remaining features of the organism in the characteristic ways of Sacculina life—namely, as the sausage-like sac, fixed to its crab-host. But there can be no question, that Barnacle growth and Sacculina development run in strictly parallel grooves.

Allusion has been made to the likeness exhibited by the "pupæ" of the Barnacle and Sacculina to the perfect and adult form of those water-fleas, which, like *Cypris* and *Daphnia* (Fig. 116, B, C), are familiar tenants of our fresh waters. The development of the "water-fleas"—under which general name very diverse beings are included—is highly instructive, in that it leads us to note how the community of development existing among Crustacea extends its roots so as to include every group or order of that class within its limits. The *Cypris* (Fig. 116, B) and its neighbours are known by their possession of a distinct bivalve shell—that is to say, a shell consisting of two pieces, united along the back by a membrane serving as a hinge. Two or three pairs of feet exist, but these creatures appear to swim chiefly by aid of the tail. Now, the young Cypris leaves the egg as a "Nauplius" with three pairs of limbs. It possesses, like the Barnacle-nauplius, a single eye, and it appears to develop a shell likewise. The adult condition is attained in due course, with the production of the bivalve shell; and the three pairs of limbs of the "Nauplius" are converted respectively into the greater and lesser pair of antennæ and into the mandibles or jaws of the adult. The other feet of the full-grown Cypris are also developed in its later stages of growth, which are manifested by frequent moultings of the skin. A young Cypris therefore resembles a young barnacle in its Nauplius-form, and in the transformation of its anterior limbs into antennæ or feelers, which, in the water-fleas, serve the purpose indicated by the latter name—or may even be used for swimming, as in the *Daphnia*, or "branch-horned water-flea" (Fig. 116, C). In the correspondence between the bivalved Cypris and the pupa Barnacle or pupa Sacculina, we may possibly discover, likewise, the ultimate point of divergence between these diverse groups of Crustaceans.

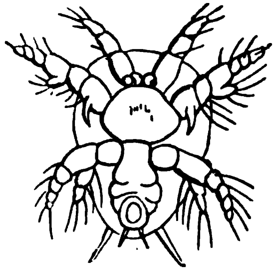


FIG. 122.—NAUPLIUS OF CYCLOPS.

Other water-fleas, such as *Daphnia* and *Cyclops* (Fig. 116, C, A), present variations in their early history from the chronicle of Cypris development. The Cyprides are perhaps the least modified of the water-flea race; this conclusion being supported by the greater complexity of other water-fleas as well as by the course of development of the latter. The anatomical investigation of a Cyclops presents us with an oval body or carapace (Fig. 116, A), bearing a single eye; with two pairs of feelers, big and little; with a jointed tail, forked at its tip; and with five pairs of swimming feet. In Cyclops-development a singular resemblance is presented to that of certain low crustaceans parasitic on fishes: and it will be instructive therefore to compare these early stages in both groups. The first stage in Cyclops-history (Fig. 122) repeats the now familiar "Nauplius," with its oval body, its central eye, and its three pairs of legs. Next are developed the chest and tail regions; and six feet appear as the belongings of the latter. Then appears another pair of limbs; and the three limbs of the Nauplius become the greater and lesser pairs of feelers, and the great jaws, as in Cypris. After a series of moults, the outlines of the Cyclops-body begin to be apparent; but it is worthy of remark, that beyond the stage in which the tail-region with its six feet is developed, those lower and parasitic crustaceans — the fish-lice just referred to — do not pass. The further history of Cyclops is simply a record of moults and the growth of new joints and appendages; that of the fish-lice is a history of retrogression. The fish-lice are represented by such forms as *Lernæocera* (Fig. 123), or *Chondrocanthus*, which latter in its maturity may be found sometimes by the dozen in the gill-chamber of that ungainly fish the Angler or Fishing Frog (*Lophius piscatorius*). *Lernæocera* presents us, as an adult, with a shapeless flattened body, about half an inch long, possessing the merest rudiments of limbs. Each fish-louse begins life as a Nauplius (Fig. 123, B), essentially resembling that of the Cyclops water-flea (Fig. 122). It develops to resemble still more thoroughly the after-stages of Cyclops, but retrogresses therefrom and becomes modified for a parasitic life.

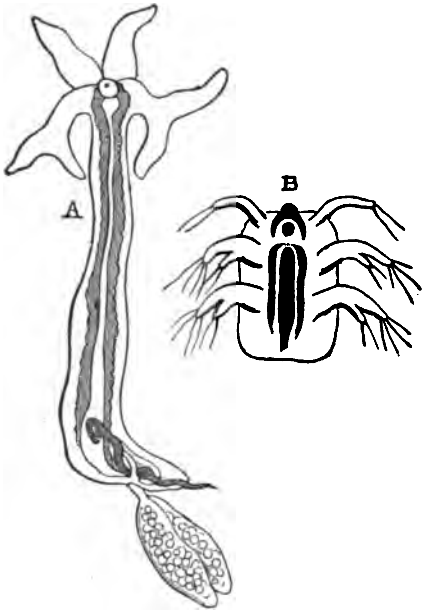


FIG. 123.—FISH-LOUSE AND ITS NAUPLIUS.

Still more marked is this modification in other fish-lice (*Actheres* and *Lernœæ*) which resemble Cyclops as closely as does Lernœocera, but which, sooner or later, become worm-like or otherwise degraded. The suppositions, entertained by competent authorities, firstly, that the fish-lice (Fig. 123) and water-fleas of the Cyclops-type (Fig. 116, A) have sprung from the same stock; and secondly, that the fish-lice are simply Cyclopean beings degraded by the adoption of parasitic habits, are therefore fully warranted by a consideration of the plain facts presented to us in their development. Or once again, to state a cardinal proposition of Evolution—the passing development of individuals repeats and reproduces, with modifications, the fixed and past development of the race and class.

To trace in full the record of Crustacean development would considerably exceed the limits which the patience of the reader might bear, and would unnecessarily protract and repeat facts already exhibited and illustrated by the life-histories just recorded. It might be highly profitable, for instance, to trace the development of those peculiar Crustaceans, the King Crabs or *Limuli* (Fig. 124), which, as living forms, stand well-nigh alone in their class, and remain connected with other Crustaceans only as the leaves on the extremities of one branch of a tree may be said to be connected with those at the tip of another and widely divergent bough. These crabs at one stage of their development, and before leaving the egg—within which all their notable features are acquired—present a most remarkable resemblance to certain of those singular fossil crabs the Trilobites (Fig. 125), (*Prestwichia*), and likewise at another stage to the larva of certain other Trilobites (*Trinucleus*). This resemblance is well seen on comparing the larva of the King Crab (Fig. 126, B) with the larval Trilobite (A); and still more striking is the resemblance between the King Crab at a later stage (Fig. 127) and the adult Trilobites (Fig. 125). Thus, whilst the Trilobite-race and their neighbours (*Eurypterida*) of Silurian age have died out of existence, the King Crabs, springing presumably from the same root-stock, have undergone modification as descent proceeded along "the files of time," and remain to present a crab-race of an age and type, compared with which our existing crabs are but as creatures of yesterday. So also we might, did space permit, strive to show that those curious creatures, the Brine Shrimps (*Artemia* [Fig. 128, *a*]) of the Lymington salt-pans and the Great Salt

FIG. 124.—KING CRAB.

Lake; the Fairy Shrimps, which, like Crustacean ghosts, flit through our fresh waters; or the curious *Apus*, with its sixty pairs of feet, begin life each as a Nauplius (Fig. 128, *b*), bearing either two, or the statutory three pairs of limbs. And the account of other Crustaceans in which

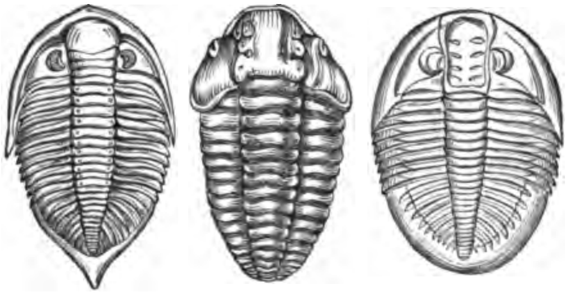


FIG. 125.—TRILOBITES.

(as in the woodlice tribe) the Nauplius-stage is passed either within the egg or is altogether suppressed, might similarly bring again before our mental view the operation of the laws and principle of modification.

It may, however, suffice, if, in drawing Crustacean history to a close, we select a few examples of development from the highest and most specialised group of the class—that of the Crabs, Shrimps,

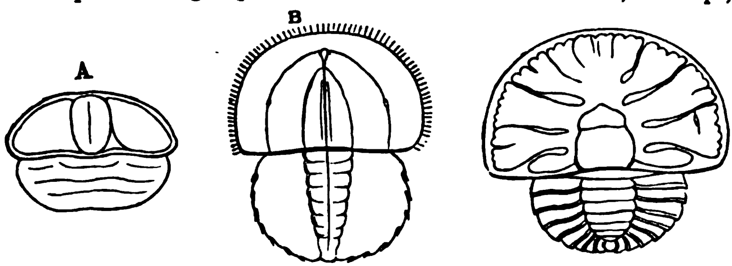


FIG. 126. FIG. 127.
LARVÆ OF KING CRAB AND TRILOBITE.

Prawns, &c. In such a history, we may discover the important fact that, notwithstanding modification, and despite the high specialisation of these latter animals from the primitive types and root-stock of Crustacea, their community of descent with that of all other members of the class is proved by those clues and traces, which, all-insignificant as they may appear to the ordinary observer, literally afford to the zoologist proofs and confirmations of the strongest character of the truth of the theory of descent.

The higher Crustaceans (or *Decapoda*, as they are called), including the Crabs (Fig. 115), Lobsters, Shrimps, Prawns, &c., as their typical representatives, present us with a sufficiently diverse group of beings viewed as adults, and likewise afford illustration of equal diversity in their development. Such diversities may be well observed in the comparative study of the early history of such a series of forms as is presented by the lobsters and crayfish, by certain shrimps, and by the common crabs. In its development, the crayfish apparently presents but little that is remarkable, as compared with Crustaceans of lower nature. Both crayfish and lobster come from the egg (Fig. 129, *a*) in the essential guise (*b*, *c*) of their species or race; and the free-swimming "Nauplius-stage," so universal amongst lower Crustaceans, is apparently unknown in their life-histories. There is clear evidence, at the same time, to show that a "Nauplius" condition is represented in their egg-development, and that this phase is obscured and modified, presumably through those causes and conditions which have placed the lobster and crayfish amongst the aristocracy of the Crustacean class. Speaking of the development of the Crayfish and of its Nauplius-stage, Huxley says, that animal "is wholly incapable of an independent existence at this stage, and continues its embryonic life within the egg-case; but it is a remarkable circumstance that the cells of the epiblast (or outer layer of the developing body) secrete a delicate cuticula, which is subsequently shed. It is as if the animal symbolised a Nauplius condition by the development of the cuticle, as the fœtal whalebone whale symbolises a toothed condition by developing teeth which are subsequently lost and never perform any function."

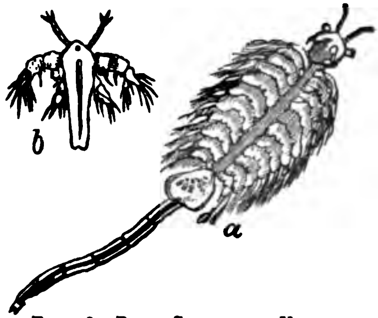


FIG. 128.—BRINE SHRIMP AND YOUNG.

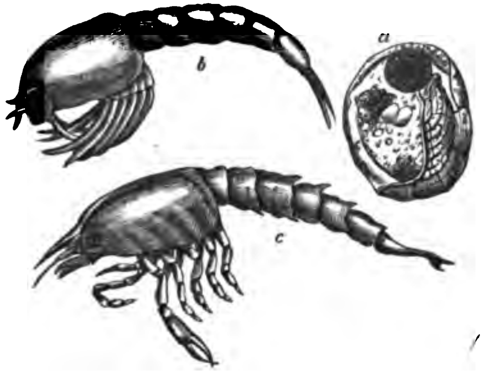


FIG. 129.—DEVELOPMENT OF LOBSTER.

Again, speaking of the Crayfish, Huxley says: "In this Crustacean, in fact, it would appear that the process of development has undergone its maximum of abbreviation."

As already remarked, the progressive advance and evolution of a group must naturally include in their course, changes and modifications in development as part and parcel of the higher order and structure to which the advancing members of the group attain. It is not surprising, therefore, to find that the crayfish or lobster (Fig. 129, *b*, *c*) should evince an absence in their development of those phases and repetitions of their ancestry, of which their lower and more primitive neighbours, the barnacles, &c., present such typical examples. Whilst, at the same time, it is equally notable and interesting to discover that in Nature's process oft-repeated exceptions prove the rule; and that here and there, the exceptions to the ordinary development of higher Crustaceans certainly prove that their original way of evolution has lain through the pathways so plainly marked out in the lower ranks of the class. Such exceptions occur within the family circle of the crayfish and lobster kind; and are even represented in the early history of that most familiar of Crustaceans, the common crab itself. This animal possesses a life-history, which, whilst it presents striking analogies to that of lower Crustaceans, likewise offers some interesting points of difference from the development of the latter animals. Within the egg, as in the case of the crayfish, the youthful crab appears to pass its Nauplius-stage, and sooner or later it emerges upon the world of waters in a form with which our previous researches have not made us familiar. The young crab (Fig. 130, *a*) possesses a short body, which at first sight appears like a huge head, and a jointed tail. In front and above, are spinous projections, the upper of which reminds one of the end of a nightcap long drawn out. A single and simple eye is placed between two very large compound organs of sight; four antennæ or feelers exist, and three pairs of jaws are developed—the young crab thus presenting us with the complete furnishings of the head of the adult. There likewise exist traces of appendages which represent foot-jaws in the full-grown crab, but the jointed tail

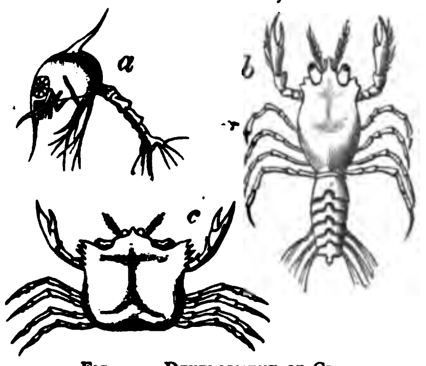


FIG. 130.—DEVELOPMENT OF CRAB.

possesses no addenda or belongings save bristle-like processes attached to its broad and divided extremity.

In 1778 there was figured by a Dutch naturalist a new form of Crustacean which was met with in 1822 in large numbers in the Cove of Cork by Mr. Vaughan Thompson. These beings were referred to a genus *Zoëa*, which had been constructed for their reception. Later research, however, showed that the Zoëas were merely the young or larval crabs, just described, and the further development of the Zoëas was in due course satisfactorily traced. For, after repeated moults, the Zoëa becomes the *Megalopa* (Fig. 130, *b*). Its body has now assumed a shape distantly resembling that of the mature crab, and its five pairs of walking legs are well developed. It possesses, however, an appendage, unknown in the adult crab, in the shape of a jointed tail provided with appendages; and as the Megalopa, the crab bears a very decided resemblance to one of its tailed neighbours, such as the hermit-crab, lobster or shrimp. Ultimately the body widens, after further moultings; the tail decreases in size, loses its appendages, and becomes tucked up under the body, to form the characteristic little "purse" of the adult crab; and, finally, with the proportional growth and development of other regions and parts, the features of adult crab-life (Fig. 130, *c*) are duly produced. Thus a crab's body really consists of a greatly broadened head and chest, and the jointed tail we see in the lobster or shrimp is represented in mature crab-existence by the little appendage or "purse," which, on examination, will be found to bear rudiments of the tail-appendages so typically developed in the long-tailed neighbours of the crab. It likewise becomes clear from the foregoing life-history, that the crabs, in respect of the modification and disappearance of their tail, are a later and higher race than the lobsters, shrimps, and prawns. And geology confirms this surmise, inasmuch as the lobster-races were developed ages before the crabs. Fossil kith and kin of the lobsters occur very early in the stratified rocks, the crabs being late productions; so that the idea of the crabs having originated from a tailed Zoëa-like or lobster-like race is fully supported by the best of evidence.

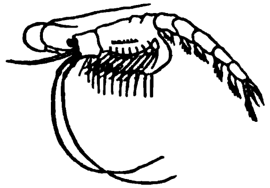


FIG. 131.—MYSIS.

The concluding life-histories which may be glanced at, by way of summarising the ways of the crustacean evolution, are those of the *Mysis* or opossum-shrimps (Fig. 131), and a peculiar genus of prawns known as *Penæus* (Fig. 132). The first-mentioned animals are common in the lakes of modern Europe and of North America, and also flourish in the Arctic Seas. It is a warrantable inference that the *Mysis relicta* of the lakes, is simply a variety of the *Mysis oculata* of the

Arctic Seas, which has been shut off from a former marine existence by the conversion of the Baltic fjords or firths into lakes; geological changes thus inducing alteration in animal species, and "a primitively marine animal" thus becoming "completely adapted to fresh-water life." These opossum-shrimps are so called, because the young are carried during development in special sacs or pouches of the parent form. They present in their early history a very interesting connection between the marked change of form in lower crustaceans, and that direct development of the higher forms of which the crayfish is so well-marked an example. Within the egg, *Mysis*, like the crab, passes through a Nauplius-stage. Thereafter, however, it grows rapidly; and a remarkable circumstance has to be chronicled, namely, that the original skin or integument remains unaltered, and is not moulted, or otherwise made to participate in the succeeding growth of the body. In this feature, as Huxley remarks, the young opossum-shrimp might be justly compared to the pupa or chrysalis of an insect, since it lies, like the latter, within an enveloping skin from which, in due course, the young shrimp emerges. Here, then, the Nauplius-stage is represented as a fleeting period in development; and we see in the Mysis, when full grown, a being which has no gills, which possesses a large tail or abdomen, and a small body (or head and chest), and which has but rudimentary appendages to its tail. Notwithstanding the fact that the development of the Mysis is well-nigh direct, we must not neglect to note the important facts, firstly, that one of its nearest relations (Euphausia) actually leaves the egg as a true Nauplius; and secondly, that the form and figure of the adult Mysis itself is perfectly reproduced in the development of the crustaceans of higher type.

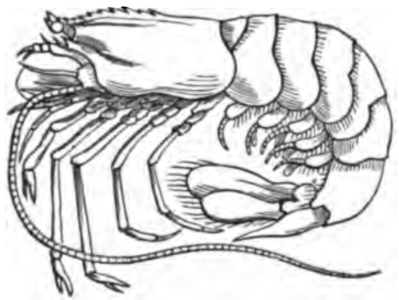


FIG. 132.—PENÆUS.

Thus in the lobster, which so nearly resembles the crayfish in its direct development (Fig. 129), and in its imperfectly represented "Nauplius-stage," the young form (named the Zoëa from its analogies to the youthful stage (Fig. 130, *a*) of the crabs), passes through a Mysis-stage, but thereafter develops into the mature lobster, with well-developed tail-appendages and "head." The idea that in the adult Mysis we may see represented a transitory phase in the evolution of such higher forms as the lobster and crayfish, is a justifiable assumption. It is one, moreover, which appears to be fully proved by the study of the life-history of that division of the prawn tribe which includes the species of *Penæus* (Fig. 132) as its representatives.

The prawns, as everyone knows, are intimately associated with the lobsters, shrimps, and crayfish as higher crustacea. Yet the first appearance of Penæus is not, as in the crayfish, as a well-nigh perfectly-formed animal, nor, as in the lobster (Fig. 129), as a Zoëa, somewhat like the adult; nor yet, as in the crab, as a Zoëa (Fig. 130 *a*), widely different from the mature form. On the contrary, the youngest stage of Penæus is a veritable "Nauplius" (Fig. 133), with three pairs of appendages, and a single median eye, accurately reproducing the features now familiar to us in the Barnacle (Fig. 119), Sacculina (Fig. 121), and lower crustacean life (Fig. 123, B) at large. Next in order, this Nauplius develops a rounded body-shield (or carapace); the first and second pairs of appendages becoming the two pairs of feelers proper to all crustaceans, whilst the third pair becomes the chief jaws or "mandibles." Then are developed four pairs of feet, converted in due time into jaws and foot-jaws; and behind these appear other five pairs of appendages which become the ten walking feet. The six joints of the tail have as yet no appendages, but the tail itself ends in two tufted processes, and we see the Zoëa-form (Fig. 134) thus limned out; whilst no less remarkable is the resemblance of the young prawn at this stage to an adult *Cyclops* (Fig. 116, A) water-flea. Two stalked eyes, in addition to the single eye of the Nauplius, appear in the Zoëa-form, which alters and changes through the decrease of the feelers, till now used for swimming.

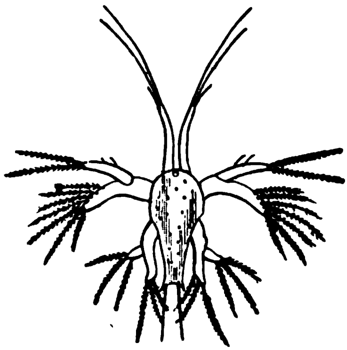


FIG. 133.—NAUPLIUS OF PENÆUS.

FIG. 134.—ZOËA OF PENÆUS.

The tail now increases in size and replaces the feelers in function; and the feelers, each at first double, become single-jointed organs. The five feet of the chest-region are each provided with two terminal joints, and the Zoëa becomes thus modelled (Fig. 135) into the exact form of a Mysis or opossum-shrimp (Fig. 131). Finally, the single and median eye disappears, the outermost of the two end joints of each of the chest-limbs disappears, leaving these walking legs (seen so plainly in shrimp, prawn, crab, and lobster) of single conformation; gills are developed within the chest, sense-organs appear, and the full development of the prawn (Fig. 132) is then completed. Throughout these varied stages it is not difficult to trace a panoramic succession of forms accurately reproducing the existing degrees and forms of the crustacean class. The early Nauplius (Fig. 133), the zoëa or water-flea stage (Fig. 134), the mysis-form (135), each produced in definite and advancing succession, present us with a perfect picture of the evolution of the prawn-race from lower crustacean life, and, presumably also, of the evolution of all other crustaceans belonging to the same rank and series in the class.

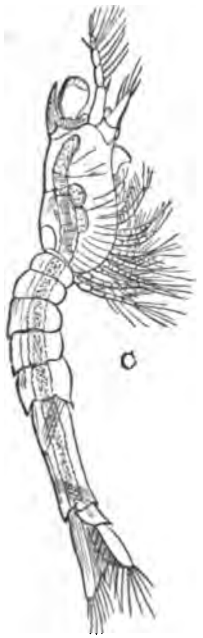
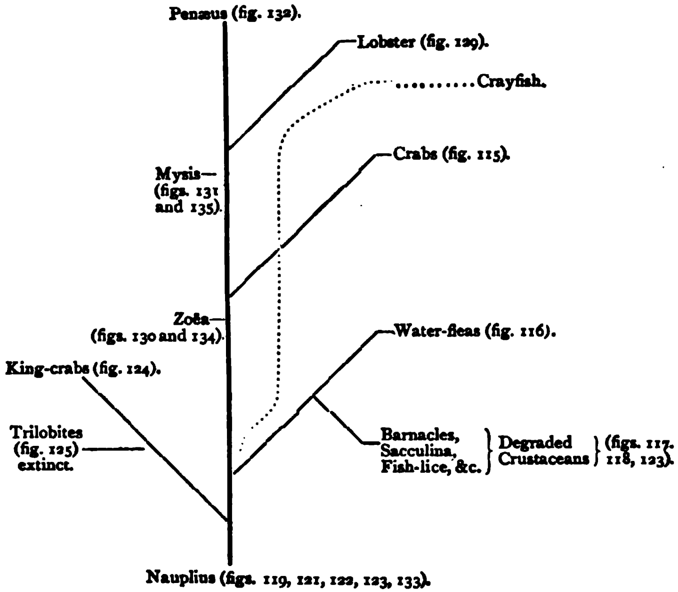


FIG. 135.
MYSIS-STAGE OF PENÆUS.

In summarising the results to which a study of the development of the echinoderms and crustaceans leads, there is to be recognised the operation of the principles already more than once insisted upon in the preceding pages, namely, that community of descent is provable by likeness in development, just as differences or obliterations and alterations in development are explicable on the grounds of adaptation and change acting concurrently with the evolution and progress of the race. Only by taking into account these two principles, can the hard ways of development be understood. The present subject is one which may be regarded as lying thoroughly without the province and power of any explanation not founded upon evolution and upon the idea that progressive change is part and parcel of the order of nature. Admitting that the only feasible explanation of these curious phases of development is to be found in such an idea of nature's constitution, it seems folly to deny that the general weight of evidence in favour of descent more than counterbalances any difficulties which may present themselves in connection with the exact determination of the lines along which that descent has travelled. That larval or young forms are themselves liable to modification from various circumstances must be admitted. This variation (to be hereafter studied in the insect-class) of the young form, which we regard as representing the primitive stock of the class, must unquestionably complicate the study of evolution and add to the difficulties of constructing a perfect pedigree of the living world. The Pluteus larva of a sea-urchin and the Bipinnaria larva of a starfish, thus differ in respect that the former possesses a limy framework which is wanting in the latter. But such distinctions do not in the least degree militate against the primary fact underlying all such developments, namely, that the likenesses, not merely of young forms, but in adult structure, are explicable only on the theory of a common origin. Indeed, with the best of reason and logic, it may be argued that, as a condition of evolution, we postulate the occurrence of variations in the young stages as well as in the adult form—just as we should legitimately expect to find in living horses the rudiments of those toes which the ancestors of the existing equine race possessed. Thus "direct" development, such as we have seen to occur in some starfishes and sea-cucumbers, whereby the young pass directly into the form of the adult, and wherein the changes of structure and appearance are suppressed, is a result of the adaptation of the larvæ to new ways of life. Rejecting this view, we should have to fall back upon the anomalous position of maintaining that there existed for one echinoderm a law of special creation, and for another a law of descent—a supposition which no logical mind will accept, and which the grander idea of the uniformity of nature at once dispels. As a final remark in connection with the sea-urchin class and its transformations, we may add that the changes in form are themselves progressive in nature. The five existing groups of this class (sea-urchins, starfishes, sand-stars, sea-lilies, and sea-cucumbers) are unquestionably modifications of a common plan of structure, and they originate from a larva which is wonderfully similar throughout, if we consider the diversities of adult structure which arise therefrom. Further, if this larva were to be arrested in its development and to represent a mature form in such an arrested stage, it would present a striking resemblance to some of the lower worms and their allies; this fact alone pointing to the probable beginnings of the sea-urchin class in a worm-stock. No less clearly do we see in the varying degrees of organisation exhibited by adult echinoderms, the same proof of progressive advance and modification of an originally primitive type. The forces and powers which, before our waking eyes to-day, evolve a sea-urchin from its egg and easel-like larva, or a starfish from its Bipinnaria, are, if we will only consider the wonderful nature of the transformations involved, engaged in as evident and intricate a work of evolution as those which have developed the varied twigs and branches of the Echinoderm tree in the æons of the past.

The foregoing conclusions find, perhaps, plainer illustration in the history of the Crustacean class, wherein exists a uniformity not so clearly traceable—although its original existence may not be doubted—in the early life of the echinoderms. The highest members of the crustacea are, as we have noted, the lobsters, crayfishes, shrimps, crabs, and their allies. We have seen that in the crayfish a "Nauplius"-stage is represented; that in the lobster a Zoëa-phase is seen; that Mysis likewise exhibits a Nauplius, and then settles down as a peculiar form; that in the crab's early history, a still better marked Zoëa appears; and finally, that the shrimp Penæus actually passes through a Nauplius phase, a Zoëa or water-flea stage, a Mysis form, and finally assumes the likeness of the shrimp tribe. The history of Penæus, therefore, is practically an abridged treatise of the evolution of all higher crustacea: its development, to parody Pope's line, is "not one, but all Crustaceans' epitome." And as perfectly are the facts of lower crustacean life correlated with those of the higher development of the class. A water-flea, like Cyclops, as an adult, matures its development and ceases to progress at a stage corresponding to that at which Penæus has but attained its youth. The barnacles and sacculinas exhibit the influence of conditions of parasitism acting at a definite stage in the course of ordinary development, and producing the degraded and attached form of the adults. Mysis advances so far on the way towards the lobster and crayfish type, but stops short in its development at a point represented in lobster history, and beyond which the lobster itself passes as we have seen. Finally, beyond all such stages, and underlying all the variations and obscurities even of the higher and most modified life-histories, we see the Nauplius-form continually appearing as the starting-point of all crustacean history; or as that point, to use Fritz Müller's expression, which represents the "extreme outpost of the class, retiring furthest into the grey mist of primitive time." The Nauplius appears before us, then, as the founder of the crustacean race. The Zoëa is a modification and advance upon the Nauplius; and from this Zoëa (as poved by Penæus-development) were evolved the higher crustaceans at large. The lobsters and their allies (again appealing to Penæus) were evolved from the Zoëa-form through an intermediate stage represented to-day by the Mysis or opossum-shrimp; whilst the short-tailed crabs, in all probability, arose directly from the zoëa, without the intervention of a Mysis-stage, seeing that in their development they exhibit a distinct Zoëa-stage, and do not pass through a Mysis-stage like the lobsters and their long-tailed neighbours.

Diagrammatically expressed, we may see in the history of crustaceans that tree-like arrangement of their pedigree which best illustrates the deductions of evolution. The Nauplius exists at the root of the class. Developed in direct line, we find Penæus passing through the Zoëa and Mysis-stages. The lobster branch diverges after the Mysis-stage has been attained, and the crabs depart from the main stem before the latter phase. The crayfish, with its obliterated Nauplius-stage, may be presumed to have followed the course of development resembling that of the lobster; its history, however, being singular in respect of the obliteration of the intermediate stages. The king-crabs have presumably originated in the common Nauplius-form, and have passed through the Trilobite-form, now extinct, to their present position at the extremity of an isolated branch of the crustacean tree; although, indeed, some naturalists hold that the king-crabs are more nearly allied to the spiders and scorpions, than to the Crustaceans. The barnacles, fish-lice, and water-fleas, obviously nearly allied, spring from a distinct Nauplius-stem, but diverge through different ways and paths of life—the former to exist mostly as degraded parasites, and the latter to develop into



active free-swimming forms. Thus becomes clear to us the meaning of those singular changes in animal forms which puzzled the older naturalists. To question the meaning which evolution attaches to these changes, is to leave them without explanation or meaning. Our knowledge of the full evolution of the Crustacea or any other animal group, as already remarked, may be, and often is, far from perfect. We are, it is true, still in the "grey mists" of many biological subjects, and the pedigree of animals, amongst others, is still enveloped in much obscurity; but, at the same time, we can detect breaking through the mist, gleams of knowledge—bright forerunners of that flood of light which the research of after-years will assuredly bring.

XI.

THE EVIDENCE FROM DEVELOPMENT (*concluded*).

III.—THE DEVELOPMENT OF MOLLUSCS, AMPHIBIANS, &c.

THE attempt has been made in previous chapters to show that in the development of living beings there lies an enormous store and fund of evidence which goes either directly to support evolution as a rational theory of the universe, or which, at any rate, aids us in comprehending the causes which have, directly or indirectly, made the world of life the wondrous thing it is. The result of our inquiries has been to show that in the first beginnings of an animal's development, and in its earliest phases of progress, there is an amazing likeness to the early stages of every other animal's progress towards maturity. But even after these early similarities have appeared, there may be demonstrated in many groups a later likeness, which may often be traced beneath forms of the most diverse kind. The progress of the living being is unquestionably, as Von Baër aptly put it, one from the general to the special. Thus a sponge, a sea-squirt, and a man, may and do agree in the essential phases of their earliest development. But the special features of each group of sponges, sea-squirts, and quadrupeds are soon respectively assumed, and, finally, there appear those more defined structures which mark the completion of development, and which land us within the class, order, or even species to which each belongs. Development may thus be compared to a journey in which all the travellers, or developing animals, start from a common point, and in which all pursue at first a common path that shortly, however, branches out into numerous diverging roads and routes, each leading to the goal or destination of the race. Community of origin is proved by two animals following the same beaten track for a longer or shorter distance; dissimilarity arising when their pathways diverge and the route divides.

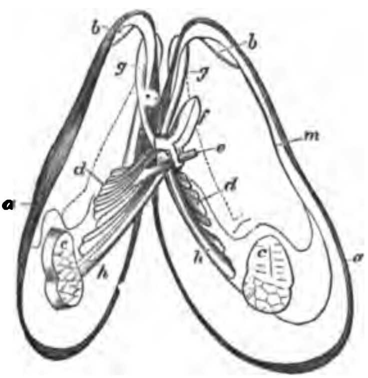


FIG. 136.—MUSSEL.
Shell opened, showing ligaments, muscles (*c c*), and foot (*f*).

Thus much for what is observed in the development of animals, as already illustrated in these pages. What is to be inferred by the biologist from the facts of early development? The reply was clearly enough given in the phrase, "development repeats descent;" or, otherwise, "the history of an individual's development presents us with a panoramic or changing picture, more or less obscured, of the descent or development of its race." In the absence of such a thought, all development is a mystery. Rejecting the idea that the phases of individual development repeat the evolution of the species, we may only say that the facts of natural history are either each a senseless paradox, or "form a mere snare to entrap our judgment." Even in the later developments of animals, we were able to trace, as we have seen, striking likenesses, provable only on the theory of evolution. The mere reference to Crustaceans and Echinoderms, will suffice to indicate the grounds on which the latter assertion is based; whilst the history of the insect-class in its developmental aspect will shortly be shown to teach the same practical and pregnant lesson. It might be thought that the teachings of development had by these examples received copious enough illustration. But there remain for notice one or two life-histories which, whilst they may trench upon fields already treated, possess yet an interest of their own. It is to these latter examples that we now refer by way of a closing reference to the early history of animals at large.

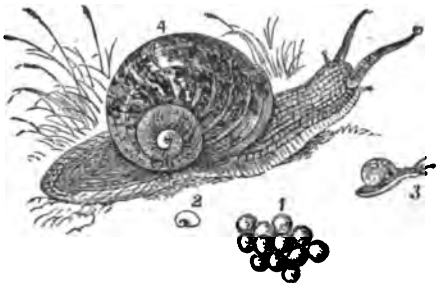


FIG. 137.—SNAIL.

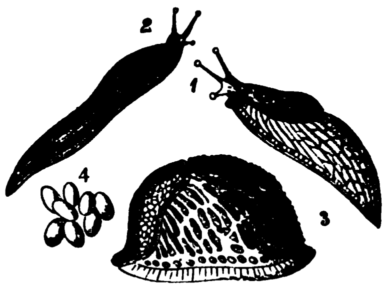


FIG. 138.—SLUGS.

Above the rank of the insects, or at least in a different group of the animal world from that in which they are contained, we may find plain illustration of that connection between apparently different classes of animals which evolution explains in rational and consistent fashion. The group of the *Mollusca*, known popularly as that of the "shell-fish," and having as its typical members the oysters, mussels (Fig. 136), cockles, snails, whelks, and cuttlefishes—the latter existing at the head of the group—presents us with one or two typical examples of the truths and inferences of development. There are at least four well-marked classes in the Mollusca, and the names of these four groups may be placed before the reader by way of enabling us to retain their distinctness clearly in mind. Thus, firstly, we find the class *Lamellibranchiata*, or "bivalves," represented by the oysters, cockles, mussels (Fig. 136), clams, &c. Then succeed the *Gasteropoda*, of which the snails (Fig. 137), slugs (Fig. 138), limpets, whelks, chitons (Fig. 139), &c., are examples. The *Pteropoda* form a small class, often popularly named "sea-butterflies" (Fig. 140), and of this group the *Clio* and *Hyalæa* (C) may be selected as representatives; whilst last and highest come the *Cephalopoda*, or cuttlefishes (Fig. 141), of which the familiar octopus, the argonaut, and nautilus are examples.

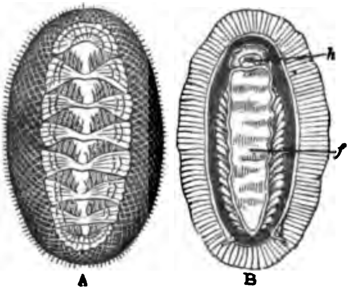


FIG. 139.—CHITONS.
A. Upper surface, showing the shell.
B. Under surface, showing head (*h*) and foot (*f*).

Such is the constitution of the Molluscan type of animals. When we study the development of the three first-mentioned classes, we are struck by the similarity they present in their early history. The

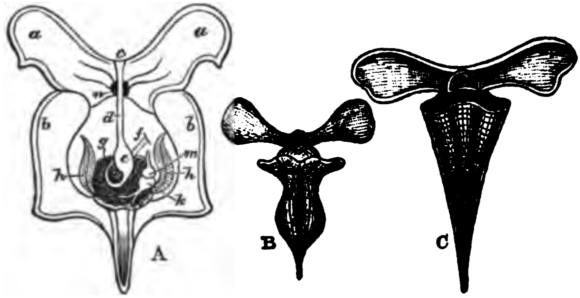


FIG. 140.—PTEROPODA.
A. Diagram of structure; B. Cleodora; C. Hyalæa.

cuttlefishes, it may be mentioned, differ from the other groups in development, and present us with an ancient and early specialised group of beings whose early history and evolution is really a matter of geological interest, and lies without the limits of the present chapter. The early stages of a bivalve, such as a cockle, to select a familiar member of the first of the classes just noted, exhibit the usual process of segmentation of the egg common to all animals. Sooner or later, however, the young bivalve develops a somewhat rounded body (Fig. 142, A) at the upper or head-extremity of which appears an expanded disc—often described as consisting of two distinct lobes or halves—richly fringed with the minute vibratile processes called *cilia*, and named the *velum* (*v*). In the centre of this velum, an elongated tuft of cilia is usually found in addition, the tuft being known as the *flagellum* (*fl*). Thus provided with its vibratile "hairs," the young bivalve swims freely through the sea, and is thus said to exhibit its "veliger stage." Then a patch of substance forms on the back of the embryo. This becomes the mantle which lines the shell, and in fact forms the latter structure; whilst in due course the internal organs are developed, and the young shellfish assumes the likeness of the adult. The oyster and cockle are thus seen to pass through a veliger stage (Fig. 142, A), each with its ciliated lobes and its free-swimming powers, through the exercise of which the oyster-spat may be conveyed to great distances from its birthplace. As we shall presently note, the likeness of this wandering embryo to the young of certain lower animals is distinctly marked.

FIG. 141.—CUTTLEFISHES.
The upper figure represents an Octopus swimming backwards.

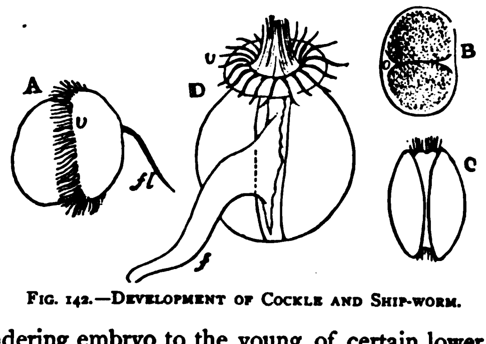


FIG. 142.—DEVELOPMENT OF COCKLE AND SHIP-WORM.

The curious ship-worm, or *Teredo* (Fig. 143), which was termed by Linnæus "calamitas navium," and which effects an immense amount of destruction annually on the wood of our piers and harbours, is in reality a bivalve mollusc. Its body is shortened and its breathing-tubes are extended to form the worm-like body, whilst its shells (Fig. 143) are rudimentary and serve as boring-organs. The teredo first undergoes segmentation within the egg (Fig. 142, B), and then appears as an active free-swimming "veliger" (Fig. 142, C), differing from the young cockle only in that there is no lash-like "flagellum." Then its mantle and shell are formed, and when five and a half days old, the shells have well-nigh invested the whole body. Next the "foot" (*f*) of the ship-worm is developed, and the velum becomes a crown of cilia (D *v*). Then, as the young animal seeks the wooden pile wherein it is destined to bore and ensconce itself, the shells come into play as excavating organs, and, with the growth of the elongated body, ship-worm development may be said to conclude. Thus we find that the course of bivalve development is distinctly enough marked. Only in one or two cases (such as that of the fresh-water mussels, *Unio*) is the "veliger-stage" suppressed. But this latter fact will cause no surprise to the student of development, who is well aware that the effects of varying conditions on the developing young are seen in the production of many changes in an early life-history, and in rendering obscure many phases in the panorama of individual evolution.

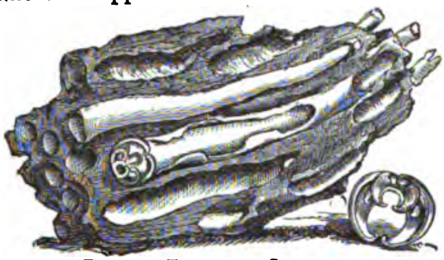


FIG. 143.—TEREDO, OR SHIP-WORM, Showing the shell detached.

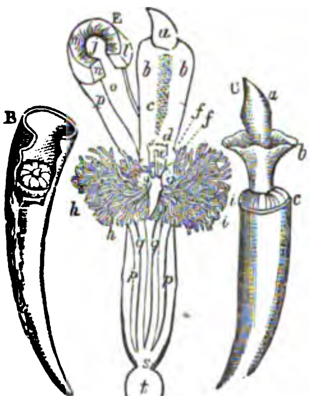


FIG. 144.—DENTALIUM AND ITS STRUCTURE.

Coming next to the Gasteropods, of which the limpets, whelks, snails, slugs (Figs. 137, 138), and the univalve shell-fish at large, are examples, we find a striking similarity in their early history to the development just sketched. A mussel, or oyster, or other bivalve has, as every one knows, no distinct head. This may be the result of degradation. But in the snails, whelks, and their neighbours, the head is plainly enough marked, although in certain low forms of the Gasteropod-class this head-development may not be at all prominent. Such lower members are illustrated by the *Dentalium* or "toothshell," otherwise often named the "elephant's tusk-shell" (Fig. 144, B), from its obvious resemblance to the latter structure. In the early history of Dentalium, we find obvious resemblances to the development of the bivalves. First, segmentation or division of the egg takes place (Fig. 145, A). Next, the young "toothshell" on escaping from the egg appears as a rounded body, and possesses tufts of cilia for swimming, and likewise has a "flagellum" (*z*) in front (B). The body then lengthens and develops seven circlets of cilia (Fig. 145, C), the resemblance between the young "toothshell" in this guise and an embryo worm (Fig. 157, B) being unmistakable. Then the shell is formed by the "mantle" (Fig. 145, D, *a*) as before, and the cilia form a "velum" (*z*) at the upper extremity of the body, the young condition of the bivalve being closely imitated at this stage. The shell, at first open below, unites by its lower edges to form the toothlike structure of the perfect animal, and with the further growth of the internal organs (E), Dentalium becomes the mature animal. There cannot exist a doubt that, as the lowest gasteropod, and as a poor relation of the higher whelks and snails, Dentalium's life-history shows, as might be expected, the closest approach, firstly, to animals of lower grade than mollusca, and, secondly, at a more advanced stage—that of the "veliger" (Fig. 145, C, D)—to the bivalves themselves.

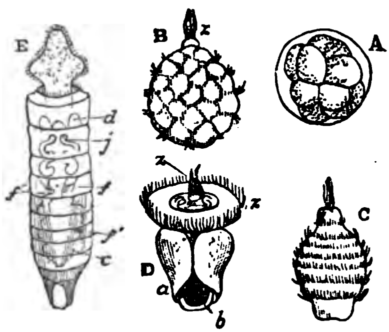


Fig. 145.—Development of Dentalium.

Equally interesting is the chronicle of development which those little limpet-like animals, the *Chitons* (Fig. 139), present to our view. These latter forms are found adhering to the rocks and stones at low water, like the neighbouring limpets. They agree with the limpets in being Gasteropods; but their structure is, if anything, lower than that of the familiar molluscs just mentioned, and their shell is not univalve, but composed of no fewer than eight pieces (Fig. 139, A), arranged one after the other, on the animal's back. No definite head, however, is found in the chitons, this lack of front extremity being, as before, a proof of lowness and democracy in the scale of Gasteropod society. The general aspect of a chiton is unquestionably more like that of an "articulated" or jointed animal than of a mollusc, in which latter we do not expect to see segments of any kind represented. It is likewise a fact of much interest that these chitons are a remarkably ancient group of the Gasteropod-class. They may, it is true, be regarded, by the strict rules of comparative anatomy, as lower organisms than the whelks and their relations. But if antiquity of origin be esteemed in the Gasteropods, as it is in higher circles, a criterion of respectability, then the chiton race may claim a superior rank to many of their neighbours, and may maintain that when the univalve race was but in the infancy of its development, they possessed a stable and well-founded family connection. The chitons begin their fossil history in the lower Silurian rocks, and appear at the present time with but little variation from their past structure. They are, therefore, unquestionably an ancient series of beings, which have most probably sprung from a far back root-stock, whence the Gasteropods themselves, and other molluscs likewise, may have branched off to become the superior shelled races and tribes of to-day. What, then, is the course of chiton development? As we should expect, it is much more primitive, much nearer the type of the worms and of Dentalium development, than that of other univalves. The researches of Loven have made us acquainted with the early history of the chiton group. From the egg, the infant chiton (Fig. 146, A) issues forth as an oval speck possessing a circle of cilia surrounding its body near the front extremity, and likewise bearing a tuft of cilia on its head, The likeness between the young chiton and the young cockle (Fig. 142, A) is clearly traceable. An eye-spot soon appears on each side of the ciliated circlet, and the body next becomes annulated or ringed in appearance (B), such an aspect reminding one most forcibly of the young stages of the worms (Fig. 157). Even when the young chiton exists in this free swimming state, the segments of the shell begin to appear (C), and correspond with the rings into which the larval body is divided; whilst subsequently the broad "foot" is developed, and the animal settles down into a sedentary and placid existence on the rocks and stones of the coast. Chiton development thus tells a tale of early origin, and of alliance with the worm stock. In this respect it forms a worthy companion to Dentalium itself.

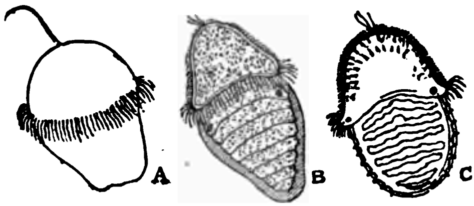


FIG. 146.—DEVELOPMENT OF CHITON (LOVEN).

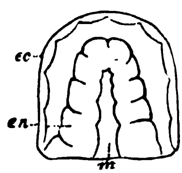


FIG. 147.—POND SNAIL, GASTRULA-STAGE.

The development of the familiar pond snail (*Lymneus*), as studied by Professor Ray Lankester and others, may render us acquainted with normal gasteropod development in its higher and most typical phases. The eggs of the pond snail are to be found in June deposited on the under surface of the leaves of water-plants, enclosed in capsules containing a white jelly-like matter. The egg undergoes complete yolk segmentation, and then the "gastrula-stage," with its two layers (Fig. 147, *ec*, *en*)—repeated in all animals from sponge to man—appears. The mouth of this sac closes as the young form passes to enter the "veliger stage," in which the body is oval, and possesses a ciliated ridge. This latter stage has also received the name of "trochosphere." Ultimately the "foot" is developed, then the shell appears, and in due time the snail-form is assumed. In the pond snail, as a high form of mollusc, we unquestionably find a "veliger-stage," reminding us of the similar phase in other and lower univalves and in bivalves. It is a noteworthy fact that the land snails and slugs do not show the "velum," notwithstanding their apparent nearness to the pond snail. The suppression of the "veliger-stage" here does not surprise us. On the contrary, we are fully prepared for such lapses and omissions in development by the consideration, already enforced, that altered ways of life must inevitably produce a changed life-history. Such omissions, in fact, exactly answer the expectation of the evolutionist; and their absence would indeed prove a veritable stumbling-block to his hypothesis. In the "top-shells" (*Trochus*), familiar enough as native species, it may be mentioned that the "veliger-stage" (Fig. 148, A), or that of the "trochosphere," is well represented; whilst in this stage the embryo is also marvellously like the young of certain worms, and also resembles that of some of the *Rotifera* or "wheel animalcules." Later on, the "velum" (*v*) of trochus grows larger (B) and becomes more prominent; and as the shell develops, the larva assumes the likeness of the young "top-shell." Such a life-history is worth recording, even in a cursory fashion, if only to emphasise the fact that, even in some undoubted univalves, the likeness to lower worms is remarkable.

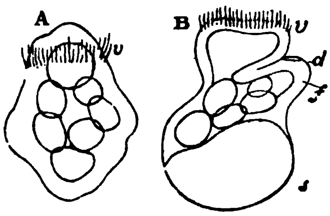


FIG. 148.—DEVELOPMENT OF TROCHUS.

Certain other univalves of somewhat different structure from those whose development has just been described, may now be noticed. These latter are the so-called "naked" gasteropods, in which a shell is either rudimentary or wanting altogether. But the curious fact remains that, whether a shell is present or not, these animals invariably possess that structure in their embryonic state. This shell, which is thus never destined to be developed, is an illustration of

" rudimentary organs," which, like the teeth of the unborn whalebone whale—possessing no teeth whatever in its adult state—have a reference to a past state of things. These teeth and the rudimentary shell are heritages derived from ancestors which had well-developed teeth and shells respectively. Otherwise, and on any other theory of nature, their mere existence is a hopeless and insoluble puzzle. The shell-less univalves to which we refer are often familiarly named " sea slugs," " sea-lemons," and the like. By naturalists they are placed in such genera as *Doris* (Fig. 149), *Æolis* (Fig. 150), *Aplysia*, &c. Other examples of these molluscs are included in the genus *Bulla*, or that of the "Bubbleshells" (Fig. 151), possessing a delicate shell, and *Aplysia*, or that of the "Sea-hares," famed of old as an ingredient in classical poison-cups. *Bulla* and the Sea-hares possess each a thin shell, which, however, is a secondary growth, and does not represent the true shell or that developed in early life. Now, in these " naked " gasteropods, there is a well-marked " veliger-stage." Moreover, if the development of such a form as *Æolis* (Fig. 150), or its neighbours of the " Sea-lemon " tribe, be studied, the young form is observed at one stage of its career to present a singular and highly characteristic appearance. It possesses a velum, consisting of two well-marked lobes (Fig. 152, A), richly ciliated, and by means of which it swims rapidly through the sea, whilst the animal's foot and its shell are also readily observable.

FIG. 149.—DORIS.

FIG. 151.—BULLA.

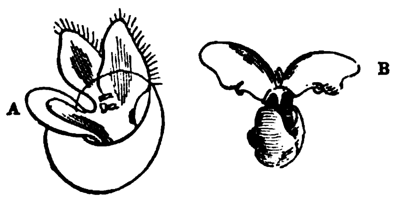


FIG. 152.—YOUNG OF ÆOLIS AND ADULT PTEROPOD.

FIG. 150.—ÆOLIS.

Far away in the Northern seas, the Arctic voyager may sometimes sail for days, or rather for nights, through water which may be discoloured by the innumerable myriads of small organisms floating on its surface. Each of these beings is of very small size—certainly under an inch in length as a maximum measurement; and each paddles or flaps its way through the sea by means of a pair of wing-like fins attached to the sides of the neck. Such are the "Sea-butterflies," or *Pteropoda* (Figs. 140 and 152, B), already mentioned as a class of the Molluscan group. Their title to be regarded as "shellfish" rests on the fact that, besides agreeing with other molluscan characters, they may possess a delicate glassy shell (Fig. 140, C); but this structure may, at the same time, be wanting, and a head may also be indistinctly represented—the latter fact indicating, as we have seen, a position of inferiority in the molluscan scale. Now, when a Pteropod (Fig. 152, B) is even cursorily regarded in the possession of its "wings" or fins, borne on the sides of its neck, its resemblance to the young (Fig. 152, A) of some of the "naked" gasteropods, such as Æolis (Fig. 150), is both close and unmistakable. In their development the pteropods possess a "velum," like most univalves. This "velum" is believed by good authorities to remain developed, and to constitute the "wings" or "fins" (Fig. 140, A, *a*) of these animals. By other authorities their "fins" are believed to represent certain side-lobes of the molluscan body, and as such are regarded by this second theory as secondary developments. However, that the pteropods represent a rudimentary or primitive set of beings no one may doubt. Let us bear in mind that they run through the same early phases of development as gasteropods, and that not only is the "velum" or "veliger-stage" represented in their history, but that certain members of their class present the cilia-girdled appearance (Fig. 153) proper to the early phases of worm development (Fig. 157). Let us also reflect that the pteropod seems to have been arrested in its development at, or a little beyond, the "veliger-stage," and we may readily understand the position of those naturalists who, comparing the *young* of the "naked" gasteropod (Fig. 152, A) with the *adult* pteropod (B), see the closest affinity and relationship between them. The pteropod in this view represents a "permanent larval" or arrested gasteropod. Both have

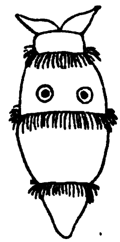


FIG. 153. LARVAL, OR YOUNG PTEROPOD.

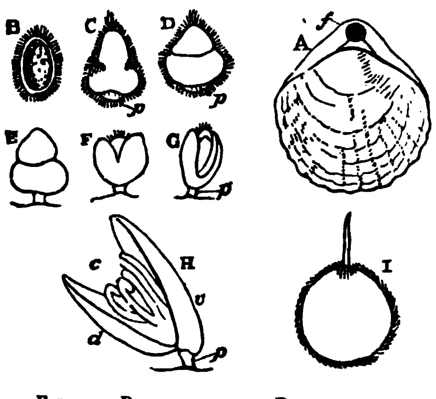


FIG. 154.—BRACHIOPODA AND DEVELOPMENT.

arisen, if the story told by development is worthy of credit, from a common root-stock, of which the "veliger-stage" is the transient representative. Both have developed in parallel, or, it may be, in corresponding and similar grooves. But the gasteropod has been evolved beyond its "veliger-stage" to assume a higher place in the animal series; whilst the pteropod has been arrested in its development at this stage, and has assumed, with possibly a little fixation of its characters, a larval condition as the badge and mark of adult structure.

Passing, last of all, to a lower group of molluscs—that of the *Brachiopoda*, or "Lampshells" (Fig. 154, A)—we may find through these latter forms a passage to the still lower and more primitive stock from which the Molluscan group may be presumed to have originated. The brachiopods form a scarce group of shellfish in our present seas, but in past epochs of this world's history they were abundantly represented. The Silurian rocks, to mention but one group of formations, literally teem with their fossil representatives, whilst the paucity of these shells in existing waters is matter of zoological notoriety. These "Lampshells" are, therefore, an extremely ancient group of living beings. That they are inferior in many phases of structure to the common bivalves—such as our oysters and cockles—is matter of fact. Hence the development of these "Lampshells" may be presumed, on *à priori* grounds, to be fraught with meaning and information as to the descent and origin of the Mollusca at large. Let us, therefore, endeavour to follow out the researches of Morse on the development of these singularly interesting forms.

Studying one species—*Terebratulina*, the common "Lampshell" of the American coast—the first free-swimming stage is that of an elongated body (Fig. 154, B), which divides itself crosswise into three rings or segments (C, D), the front one of which becomes provided with long actively-moving cilia. Eye-spots also appear on the front segment, and the likeness of the young lampshell to an embryo-worm (Fig. 157, C) is at this stage plainly apparent. Nor is the likeness lessened, when the middle segment is found to develop four bundles of *setæ*, or bristles, such as appear in the worms. Then succeeds the stage of fixation. The young brachiopod now attaches itself by its lower segment (E), and the middle segment increases greatly in size, so as to form a kind of hood enclosing the front segment in part. Then the front segment (F, G) decreases in size; the middle portion originates the bivalve shell (H, *v*, *d*), which soon comes to enclose the body (*c*), the lower or third segment being represented by the disc or stalk of attachment (*p*). The technicality of the subject prevents our following out for the reader the later stages of lampshell growth, in which striking likenesses are presented, not merely to brachiopods now extinct, but likewise to the young stage (Fig. 154, I) of those plant-like animals, named *Polyzoa*, and of which the Sea-mats (*Flustræ*) (Fig. 190, *a*) of our coasts are good examples. Hence we conclude that the Brachiopods present us with a group, which has sprung from a worm-like stock, along with the sea-mats, thus showing us the possibility of higher molluscs having had a similar origin.

The early history of the worms themselves—belonging to the *Annulose* type—forms a concluding phase in these investigations into the history of the Molluscan race. If we study the development of one of the true sea-worms, such as *Arenicola* (Fig. 155) or *Nereis* (Fig. 156), we shall find a striking reproduction of some features with which our molluscan researches have already made us familiar. The young worm (Fig. 157) makes its first appearance as an active free-swimming, barrel-shaped body, provided with cilia, disposed in various fashions, in different groups of the class. Thus, in some embryos (B, C) there is a first band of cilia around the body in front of the mouth, a second band exists at the opposite extremity, and tufts of these cilia may also be developed at the extreme front of the body. In other cases numerous bands of cilia encircle the body at its middle portion only (C); whilst a third set of cases exists where a broad zone of cilia occupies the middle region, with or without a tuft at the head-extremity. Out of such larval forms, the young worms are gradually developed, the head and front segments appearing first in the order of growth. Certain of those sea-worms which, like *Serpula* (Fig. 158), live in tubes of lime or other matters which they fabricate from the minerals of the sea-water, possess a development equally characteristic with that of their free-living neighbours. In the larvæ of these tube-dwelling worms (Fig. 157, A, D), the head is provided with cilia, disposed chiefly in two rings, one at either extremity of the body. Soon tentacles are developed from the head portion,

FIG. 155.—LOB-WORM (*Arenicola*).

FIG. 156.—NEREIS. A Marine Worm.

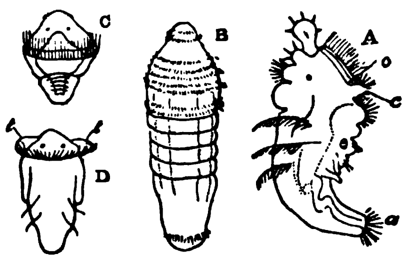


FIG. 157.—DEVELOPMENT OF WORMS.

the body becomes segmented, and the tentacle which, under the name of the *operculum* (Fig. 158, *o*), is destined to form a stopper to the mouth of the tube, may likewise be discerned. At this stage, with its segmented body, the young tube-dwelling worm resembles the permanent condition of its free-living neighbour of the sand (Fig. 156). Hence, when we discover that the tube-dweller finally secretes a tube, and lodging its body therein, becomes a stationary form, we conclude, rationally enough, that both kinds of worms have arisen from one common stock, and that the tube-dwellers represent the more modified race of the two groups; whilst they likewise may be regarded as "degraded" forms when compared with their free-living neighbours (Fig. 156).

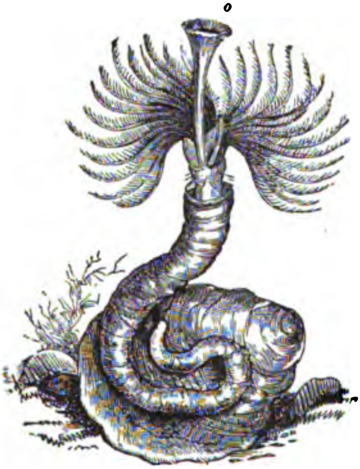


FIG. 158.—SERPULA.

We have thus had presented to view a series of developments extending from those of the molluscs, through the "lampshells," and finally ending with that of the worms themselves. Is there evidence at hand to show that something more than a theoretical conception of the connection between these apparently dissimilar forms is a warrantable thought? The answer to such a question depends on the credence we place on what development teaches. If the truth of the axiom that "development repeats descent" be not admitted, it is worse than useless to invite comparison between the larva of a chiton and that of a worm. Unless the mind has been prepared to discover in development the shifting and progressive past history of a species, there can be no benefit of an intellectual kind in comparing the likeness of the young brachiopod with the early stages of the worm. But, conversely, when it is admitted that all development is meaningless unless some idea of its use, purport, or cause is afforded, and when in the study of the phases of an animal's growth we are led to see prospects of tracing its past evolution, the likenesses and analogies of development become forcibly plain and valuable. Primarily, it may be said that a very large part of the reasonableness of evolution depends on its rational interpretations of development. Without development and its lessons, evolution would be well-nigh unprovable. Conversely, without the idea of evolution, the development of animal or plant is a meaningless piece of natural transmogrification and change.

In so far as the life-histories at which we have just glanced are concerned, the general conclusions to be drawn from their study lie on the surface of the subject. Beginning with the worms and their transformations, we find a type of larva, presenting a rounded body with variously disposed cilia (Fig. 157, B), which simply becomes segmented, and with little further change becomes the worm. From the worms to the "Lampshells" is an easy transition, for in the development of the latter (Fig. 154) we find the clearest reproduction of the features of the young worm larva (Fig. 157) in the body divided into its three segments and exhibiting its cilia and eye-spots; whilst, as Huxley remarks, the resemblance to the worm-larva is increased when we find the young lampshell developing bundles of bristles (Fig. 154, F, G), such as the worm possesses, on the middle joint of its body. From such resemblances, Huxley is more than justified in remarking that, whilst the lampshells bear a likeness in development to the plant-like "Sea-mats" (Fig. 190) and their neighbours, their development "no less strongly testifies to their close relations with the worms." Thus the evolution of a race of lower shellfish from a worm-stock is plainly enough taught by development; and such a fact testifies directly enough to the possibilities of other molluscan developments having had a similar origin.

Coming next in order to the Molluscs themselves, we find two classes—the bivalves and the gasteropods—in each of which certain primitive forms of development may be traced. The "Veliger-stage" (Fig. 142, A) may be regarded as common to both groups; and the common origin for both classes may reasonably enough be argued for and maintained on this ground alone, and apart from any plain agreement in structure. It is, however, in the lowest members of each group that we may expect to find the most marked likeness to the primitive type and root-stock from which these classes have been derived. Hence, it is to Chiton (Fig. 139) and Dentalium (Fig. 144) that we turn for aid in solving the problem before us. The young "Toothshell" (Fig. 145, C) is unmistakably a worm. Its barrel-shaped body, its circlets of cilia, its end-tuft of these appendages—all are characters which reproduce before us the embryo worm (Fig. 157, B). Nor is the early history of chiton materially different from that of the "Toothshell." The young chiton (Fig. 146, A) leaves the egg, as we have seen, with a ciliated girdle in the middle of its body, and a long tuft of cilia on its head; whilst this embryo seems to proceed even further on the worm-track, when we find its body to become segmented or divided as in the worms (B, C); these divisions becoming the shell-plates of the mature Chiton. Thus Chiton may be regarded, without exaggeration, as a worm-form existing under a molluscan guise. And when we arrive at the higher gasteropods, with their "veliger-stage" and "trochosphere," we see produced before us simply a later modification of the worm-stock. The life history of a sea-butterfly or pteropod, in fact, takes up the narrative where the development of chiton ends it. Chiton led us to the worm-larva stage, and thereafter branches off on its lower molluscan path. But the pteropod may, as we have seen, begin life as the worm (Fig. 153), and proceeds not merely to develop its "veliger-stage," but remains permanently therein; flapping its way over the surface of the sea by means of the permanent "velum," or its substitute, in the form of the fins or wings. Last of all, a gasteropod like *Æolis* presents us with a *multum in parvo* of the whole process of gasteropod and molluscan evolution. Here, we take up the story at the stage where the pteropod history concluded. *Æolis* and its neighbours (or *Lymneus*), passing through the pteropod stage, each with its "velum," develop onwards to become the higher and shelled gasteropod, and represent the furthest evolution of the race. Thus, from the worms to the lampshells on one hand, and to the chitons and "Toothshells" on the other; from these latter, in turn, to the pteropod and thence to the bivalves and gasteropods, the track of development seems plainly marked. The whole story it tells is that of a shifting panorama of the modification of the animal form; phase succeeding phase, and each new succession of forms obscuring, or it may be intensifying, the development of the preceding classes and groups. But, clearly marked or obscure, understood fully or only suggested to the mind, the whole process of development reveals to us the operation of a great law of evolution and progressive change, manifested through those wondrous cycles and transformations which nature seems never weary of exhibiting to the earnest mind and seeking eye.

If, finally, one might be tempted to inquire into the origin of these ciliated worm-larvæ themselves, we may find that speculative natural history is not unprepared with a reply. We are reminded that, as the early changes of egg-segmentation are not peculiar to the molluscs, so neither are the veliger-stages the special belongings of that group of animals. The "velum," or its representative ciliated girdles, appears before us equally in the development of the echinoderms or starfish group, of the worm, of the wheel-animalcule or rotifer, and of the mollusc. The zoologist would further remind us that these ciliary bands often remain in adult animals, and are represented by certain stable possessions, such as tentacles or feelers, gills, the "arms" of lampshells, and like structures. "It is probable enough," says Professor Ray Lankester, "that *all the ciliated bands of invertebrate embryos, even of adult organisms, can be explained as derivatives of one primitive organ.*" If this thought be fully worked out, it contains a veritable "philosopher's stone" for the zoologist; inasmuch as it enables us to account for the forms and structures of animals on a rational basis. That is to say, the particular form and structure of an animal or class, are due to the fashion in which the original ciliated bands of the larva and the embryo itself have been modified by the external and internal forces which now, as of old, operate on living things. Professor Lankester has suggestively worked out this idea of the derivation of all existing embryos from a type-form, to which he has given the name of "Architroch"—a form represented by deputy, so to speak, in certain worms and in the sea-mat class, as adult organisms. Such a theory explains to us, on a basis of a reasonable nature, how different forms may arise from a similar root-larva. And it may be added, that should any objection be urged to such views on the ground that they are entirely hypothetical, one may retort that to all other explanations of the past of nature, whether theological or scientific, exactly similar opposition may be offered. Further, we must reflect, that in any case we have to choose between filling up from our observation of nature the gaps in our knowledge which a philosophical necessity entails, or allowing these gaps to yawn unsatisfactorily and permanently unfilled. The rational mind is not likely to hesitate in its choice of alternatives. And if, lastly, it be borne in mind that, so far from being merely shadowy theories, such ideas of the origin of animal forms are based on close observation of nature—often the work of many concentrated lifetimes—the logical standing of a theory which connects the facts of nature, and by so connecting explains them, needs no justification, as it fears no honest and unbiassed criticism.

FIG. 159.—DEVELOPMENT OF FROG.

Turning now to the *Vertebrate* animals, we may find in the class of frogs and newts (*Amphibia*) material for illustrating some of the most important phases in normal development, and in altered life-histories as well. The life-history of a frog has already been alluded to in a previous chapter in connection with the evolution of lungs. It is needful, however, again briefly to refer to this life-history as a starting-point for the due understanding of other and allied cases of development. The frog begins its existence as a tadpole (Fig. 159), breathing first by external and then by internal gills, and possessing a two-chambered heart, resembling that of the fish. Sooner or later the hind limbs begin to appear, then the fore limbs are developed, and the frog's lungs likewise begin to make their appearance. At this stage, the animal resembles its neighbours, the Proteus and Axolotl (Fig. 160), which are tailed, and which breathe throughout life by both gills and lungs. Later on, the gills disappear entirely; the tail becomes rudimentary; and the frog, leaving the water, becomes the terrestrial lung-breather with which we are so familiar. To repeat Huxley's words in reference to the case for development as a guide to the history of the race: "If all living beings have come into existence by the gradual modification, through a long series of generations, of a primordial living matter, the phenomena of embryonic development ought to be explicable as particular cases of the general law of hereditary transmission. On this view a tadpole is first a fish, and then a tailed amphibian, provided with both gills and lungs, before it becomes a frog, because the frog was the last form in a series of modifications whereby some ancient fish became an urodele (or tailed) amphibian, and the urodele amphibian became an anurous (or tailless) amphibian. In fact, the development of the embryo is a recapitulation of the ancestral history of the species." That there are "ancient fishes," still represented by living species, which may have served as the starting point of the frog-race, is matter of zoological fact.

FIG. 160.—AXOLOTL, SHOWING THE EXTERNAL GILLS.

"Various features in the anatomy of the Tadpole," says the late Professor F. M. Balfour, "point to its being a repetition of a primitive vertebrate type. The nearest living representative of this type appears to be the Lamprey." This author also points out how close are the resemblances between the mouths of the tadpole and lamprey; and a still more remarkable fact consists in the observation that many of the peculiarities of the skull of the tadpole are reproduced in the skull of the lamprey. Whilst, as Professor Balfour remarks, these resemblances must be due to deeper causes than mere adaptation to similar habits, there are yet "no grounds for supposing that the lamprey itself is closely related to an ancestral form of the Amphibia." The more feasible opinion is that which would assume that both lamprey and tadpole are descended from a common and still more primitive stock. It would seem, indeed, that the ganoid fishes (of which the sturgeon, bony pike, and the fossil forms of the Old Red Sandstone, are examples) together with the allied *Lepidosiren* and *Ceratodus* (see page 113, *et seq.*), possess an allied origin from the common root of lamprey and tadpole. The facts already detailed (see Chapter VI.) concerning the development of lungs in these latter fishes, would of themselves seem to support this idea of their origin. Just as along one line of descent, the gilled tadpole-race has developed its lungs as the frogs of to-day, so, starting from the same ancestry, but developing along a different pathway, the lepidosirens and their neighbours, as if animated by like air-breathing tendencies, have developed lungs likewise. Similar tendencies towards a certain goal in development, in other words, have produced like results in the evolution of two branches of the vertebrate tree.

An interesting fact may be added to these considerations, namely, that one tadpole-form, that of *Dactylethra*, presents the closest resemblance to certain fossil fishes of the Old Red Sandstone period. These fishes belong to the ganoid type, already mentioned, and the *Dactylethra* tadpole, whilst resembling the ganoid stock, also shows affinities to the shark and dog-fish type. The latter fishes are nearly allied to the ganoids, and both appear in the geological record at once as the oldest of fossil fishes and vertebrates. This curious tadpole probably represents a period in the evolution of the frog-race, after that race had been specialised from the lamprey stage, and had already advanced somewhat on its amphibian pathway.

It therefore requires no stretch of the imagination, but the exercise of sober reason, to note, firstly, that as all the amphibian class—frogs, toads, newts (Fig. 161), and their less familiar neighbours—tailed and tailless, together begin life as tadpoles; and, secondly, that as they end, some like the frogs, tailless and gill-less, others like the proteus or axolotl (Fig. 160), possessing both gills, lungs, and tails,—the assumption remains clear that these animals have sprung from a fish ancestry. It is further matter of fact that their development has followed two pathways. In the one case the frogs and toads have passed towards a pure air-breathing existence, and have emerged from their development as land animals, pure and simple. In the other case the lower stock of the class, represented by the proteus and axolotl, &c., have retained many of their lower characters—most notably gills and tail—and have accordingly taken a lower and less modified position than the frogs and toads. The familiar tailed newts (Fig. 161), which, though living in water, and beginning life as gill-bearing tadpoles, breathe as adults, by lungs alone, represent a middle term in the series, in that they still retain the larval tail of early life.

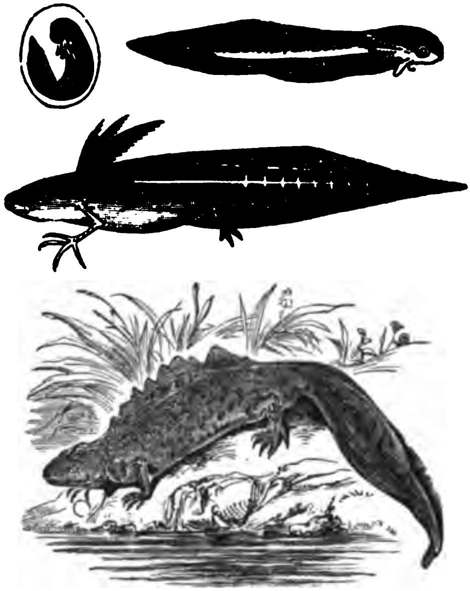


FIG. 161.—NEWTS.

Whilst the ordinary course of amphibian development runs as has just been described, there are certain exceptions of extreme interest from the evolutionist's point of view. Firstly, there are certain cases of curious development amongst the frogs themselves, which deserve a passing notice. There are peculiarities, for instance, in the carrying of the eggs, which are eloquent enough in their testimony to the singular modification of structure and habits which may accompany alteration of surroundings. Thus the tadpole form of *Pseudis paradoxa* attains a very much larger bulk than the adult. Such a circumstance points either to some nutritive condition affecting the larva, or shows that the larva reproduces some ancestral form which was larger than the living frog. The female of *Nototrema marsupiatum*, a tree-frog inhabiting America, carries her eggs in a large pouch which underlies the skin of the back, and opens behind. The larva of *Nototrema* are said to want external gills. If correct, this circumstance points to high modification in the development of this frog. A like feature to the method of egg-carrying found in *Nototrema* is seen in *Opisthodelphys*, another American frog; and *Hylodes*, likewise an American tree-frog, lays its eggs in the axils of leaves—that is, in the angle between leaf-stalk and stem—the water needful for their development being found in the chance drops resting in that situation. The male of *Alytes obstetricans* of Europe, winds the long chains of eggs laid by the female round his thighs, so that he seems to possess "trunk hose and puffed breeches," as Mr. St. Mivart remarks. Dropping, in due course, into the water, the young burst forth from the egg-coverings, and swim away, leaving their father-frog once more unencumbered and free.

Another frog (*Rhinoderma Darwinii*), a denizen of Chili, exhibits another curious modification of a different kind. Rhinoderma, like the edible frog of Europe, possesses certain "vocal sacs" or bags placed within the mouth, whereby the resonance of the mouth and the loudness of the croak are increased. It is interesting to find, however, that Rhinoderma has come to use its vocal sacs as nests; the newly laid eggs being thus received into the male parent's pouches, and the young remaining therein till they attain a considerable growth. We certainly know of male fishes in the sea-horse genus (Hippocampus) (Fig. 162), which carry the young in a pouch; and another male fish (*Arius fissus*), like the Rhinoderma, carries the eggs in his mouth and therein hatches them. In Rhinoderma the vocal sacs are greatly enlarged, and, in fact, extend on to the flanks and belly of the animal. From five to fifteen tadpoles were found by Espada in each sac, the smallest being at the bottom. The largest was about half-an-inch long, and had well-developed legs. Neither the old nor the young tadpoles had any traces of gills, and from their full development, the conclusion that the young are in some way nourished in these sacs seems by no means far-fetched. The Rhinoderma presents us, therefore, with a case in which the organisation of the male has become curiously and permanently altered to a decidedly new way of life—so much so, indeed, that the skeleton has become modified from the pressure of the curious egg-sacs of the mouth.

FIG. 162.—HIPPOCAMPUS, OR SEA-HORSE.

More curious still, on account of the very singular modification which must have produced the feature in question, is the female *Pipa Americana* or Surinam Toad, the skin of whose back becomes soft at the breeding season. The eggs are pressed by the male into this skin, which grows over them and encloses each in a kind of cell. Very curious is it to find that in the cells of the maternal back, not only the tadpole stage but the whole metamorphosis of this toad is passed. The young toads develop a long tail within the egg, this appendage being absorbed before they are hatched, whilst the useless gills disappear at a very early period in larval existence. Over 120 cells have been counted in the back of this toad, and from these cells the young emerge as miniature facsimiles of the parent. Another noteworthy case of altered development is that of the *Hylodes Martinicensis*, which passes through the whole of its metamorphosis *within the egg*, and emerges, as do the young of the Surinam toad, a perfect frog, which otherwise would require to pass several weeks in water to complete its development.

Now, to what conclusions do such facts lead us respecting the modification and alteration of development? It is perfectly clear that, as frogs and toads are normal tenants of the water in their early and tadpole stages, and are provided with gills as aquatic forms, those species which pass the whole of their development in the back of the mother, or even within the egg, must represent the most modified members of the frog class. We are therefore entitled to take their case as illustrating the best marked of the tendencies to alteration which the race presents. A frog which, like Alytes, carries the eggs, but drops them into water when they are ready to leave their primary abode, represents the first stage of modification. We are led a little farther on the way towards a suppression of metamorphosis by the case of the *Hylodes*, which lays its eggs in the axils of leaves, where moisture is relatively scarce, but where development is nevertheless undergone in due course. More advanced is the Surinam Toad, where the young pass their entire metamorphosis within the egg and in the mother's back; the *Hylodes Martinicensis* being but a further development still, seeing that in this frog the whole development is carried on within the egg, and metamorphosis is therefore practically hidden and unseen.

We may not doubt, therefore, that the amphibian class exhibits thus a tendency towards *direct* development or that without metamorphosis. Imagine the result of the later stages of such a modification of reproductive habits and customs. *Hylodes Martinicensis*, for instance, is now practically in the position of an animal which undergoes all its changes within the egg, and which, in all probability, will, in time, further shorten and condense its life-history. If such changes and modifications are occurring before our eyes to-day, is it unreasonable to regard all ordinary and direct developments—and amongst others, those of fish, reptile, bird and man—as in reality abbreviated and "brief chronicles" of once extended chapters in animal histories? A fish or bird passing through its development within the egg undergoes a metamorphosis it is true, but shortened and condensed as compared with that of the frog. There is no reason against the supposition, but every circumstance of life favouring it, that once upon a time fish-development and descent could have been as plainly seen from the outside world, as the frog's descent is traceable before our eyes to-day. Higher development and progressive tendencies invariably tend to shorten and condense the early stages of growth. Hence the value of such cases as those of the frogs and their neighbours, which, through mode of life, habits, and other and unknown conditions, have retained much of their original "way of life," and have revealed to us, through a literal byeway of development, the original and primitive phases of that of all other animal forms.

The conditions which favour or retard such developments are often obscure, or very frequently unknown. The presence of water or its absence, for instance, would favour or retard the continuance of the metamorphosis in the frog-class. We must also bear in mind that geological changes—the rising and sinking of land and the like, the conversion of swamps and morasses into dry land and similar physical changes—are powerful factors in producing modifications of habit in aquatic animals, and, through change of habit, of effecting variations in structure and form. It is possible to prove the existence and operation of such changes from many points of view. Both from the zoological or biological side, and from that of geology itself, the importance of such alterations of the earth's surface can be proved. This aspect of the subject finds appropriate illustration in works devoted to the facts of geographical distribution and their explanation; whilst we may not neglect to observe the strictly utilitarian points involved in such abbreviated life-histories as those we have been discussing. It has been noted that as we ascend in the scale of animal and plant life, development becomes more and more condensed and abbreviated. On *à posteriori* grounds we might argue that, from the fact of such condensation accompanying higher life and progressive development, some obvious advantage in the struggle for existence was thereby gained. The nature of such advantage is not difficult to discover. The more prolonged and exposed larval or early existence is, the more likely are the young forms to succumb from loss of food, change of surroundings, or from the attack of enemies and numerous other conditions. On the contrary, with an abbreviated infancy, the animal obtains a distinct "coign of vantage." There is less risk of early death, and a greater prospect of an earlier and stronger maturity. Thus the "selected races" are those which possess the shorter and more condensed life-history, and these races, therefore, come to the front in the universal struggle for existence which besets and surrounds the living hosts to-day as of yore. As Sir John Lubbock remarks, when speaking of the shortening of the insect's life-history: "The compression and even disappearance of those embryonal stages which are no longer adapted to the mode of life—which do not benefit the animal—is a phenomenon not without a parallel in other parts of the animal or even of the vegetable kingdom. Just as in language long compound words have a tendency to concision, and single letters sometimes linger on, indicating the history of a word, like the 'l' in 'alms,' or the 'b' in 'debt,' long after they have ceased to influence the sound; so in embryology useless stages, interesting as illustrations of past history, but without direct advantage under present conditions, are rapidly passed through, and even, as it would appear, in some cases altogether omitted."

We may here refer to the case of the Mexican Axolotl (Fig. 160), on account of its peculiar development, and also from its bearings on that of another member of the frog's class—the black salamander (*Salamandra atra*) of the Alps and its curiously modified life-history. The Axolotl is a Mexican eft or newt, which retains the gills of early life along with the lungs of the adult stage. It breeds freely in captivity, and hence was long regarded as a mature and adult animal. But in 1867 some axolotls were observed to emerge from the water in the Jardin des Plantes at Paris, to cast their skins, and to become transformed into a gill-less newt long known as an American genus,

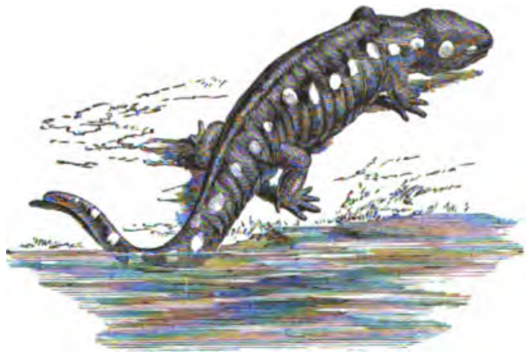


FIG. 163.—AMBLYSTOMA.

and named *Amblystoma* (Fig. 163). Such a change was almost equivalent to that whereby a frog could be metamorphosed into a toad, and hence it excited no small surprise in the zoological world. By careful experimentation a lady naturalist, Fräulein von Chauvin, showed that by gradually inuring the Axolotl first to a life amongst damp moss, and then to an existence entirely removed from the water, it could be made to assume the Amblystoma-form, with its black skin and yellow spots. Weismann states that the transformation occupies fourteen days, and Duméril states the period of metamorphosis as sixteen days.

Fräulein von Chauvin states, in her account of the Axolotl's metamorphosis, that her experiments were begun on June 12, 1874, with five larvæ, about eight days old. At the end of June the front legs had appeared in the healthiest specimens, and on July 9 the hind limbs were developed. Towards the close of November, one of these larvæ appeared to remain constantly at the surface of the water, and from this sign Fräulein von Chauvin concluded that the proper and natural period had arrived for the assumption of the Amblystoma-form. This specimen was accordingly placed, on December 1, in a vessel in which its existence was divided between a water life and a terrestrial one. The water being gradually diminished, the gills began to shrivel, and on December 4 the animal left the water, and remained on the earth and moss in the vessel. At this period, it moulted its skin for the first time. Then, also, between December 1 and 4, the dorsal crest, or fin, shrivelled in addition to the gills, and the tail became rounded like that of the Amblystoma. The original greyish-brown colour likewise changed to black, and the spots of the Amblystoma became apparent. The gill-clefts were open on December 4, when the animal left the water; but in about eight days these slits were entirely closed. In the other specimens experimented upon by Fräulein von Chauvin, the period occupied in the metamorphosis varied somewhat, the greatest differences being due, apparently, to the nutrition of these forms being less active than in those specimens in which the transformation was speedily accomplished. The general conclusion arrived at from these experiments is that "Axolotl larvæ generally, but not always, complete their metamorphosis if, in the first place, they emerge sound from the egg and are properly fed; and if, in the next place, they are submitted to the necessary treatment for changing aquatic into aërial respiration. It is obvious that this treatment must be applied very gradually, and in such a manner as not to overtax the vital energy of the amphibian." Weismann concludes that "most Axolotl larvæ change into the Amblystoma-form when, at the age of six to nine months, they are placed in such shallow water that they are compelled to respire chiefly by their lungs."

The Axolotl does not, so far as is known, become converted into the Amblystoma-form in its native region. In the Mexican lakes it appears to be perpetually and only known as the gilled Axolotl. Professor Cope also states that these Mexican animals, when bred in captivity in America, reproduce their like, and do not show any tendency towards transformation. Yet in France and elsewhere, as already remarked, the Axolotl becomes transformed into the Amblystoma in its domesticated or captive condition; but it is necessary to remark that the exact species which became metamorphosed in France was either the *Siredon lichenoides* of Baird, or some allied form, and not the *Siredon Mexicanus* of Mexico. Baird states that the former species, which occurs 7,000 feet above the sea-level in Wyoming territory, becomes transformed into the *Amblystoma Mavortium*; whilst the first Amblystomas obtained by Duméril from the Parisian Axolotls appeared to agree with another species of Amblystoma (*A. tigrinum*). If these details be taken into account, whilst they do not in the least affect the curious nature of the transformation, they would seem to indicate that more than one species of Axolotl undergoes metamorphosis; and this result is exactly that which the naturalist would be led to expect. The general condition probably affects the whole Axolotl race, and is not confined to any one species. Regarding the Amblystomas themselves, it has been already remarked that these newts are well known in America. Over twenty species are known to inhabit North America, and there can be no doubt that these animals live and breed as true Amblystomas. As Weismann remarks: "There are, therefore, true species of *Siredon* which regularly assume the Amblystoma-form under their natural conditions of life (*i.e.*, develop into Amblystomas from eggs laid by Amblystoma parents), and which propagate in this form; while, on the other hand, there are at least two species which, under their existing natural conditions of life, always propagate as *Siredon*" (*i.e.*, develop Axolotls from eggs laid by Axolotls). Observations by Professor Baird on the development of Amblystomas show that, as might be expected, the young gilled larvæ, arising from Amblystoma eggs, present a close likeness to the Axolotl race.

The case of the axolotl illustrates powerfully the effects of a change of surroundings in metamorphosing a species. A succession of dry seasons, operating in the past, has most likely been the active origin of the amblystoma race from the axolotl stock. Presumably the axolotl, as the "gill-bearing" form, is the primitive stock; the amblystomas being a derived race, but nevertheless representing a true species of which the axolotl, conversely, may be termed the "larval form." To this relationship, however, reference will be subsequently made. The shrivelling of the gills seen in the experiments on the axolotl, it is noteworthy, was probably due to a mechanical cause, that of dryness of the surroundings. Once established, the new race of Amblystomas would be propagated amidst the conditions which best suited them, whilst the axolotls have flourished amid their own aquatic environments.

This case of modification of species, however, leads to a much more typical one in which the female of the black salamander of the Alps, a gill-less newt or eft, retains her eggs within her body, and hatches them; the young likewise undergoing development, and casting their gills therein, just as do the young of the modified frogs already described. Furthermore, out of some 40 or 60 eggs, only two young are developed; the latter devouring the remaining eggs as food. Thus, whilst the young of the spotted salamander, a neighbouring species, number 40 or 50 at a birth, those of the alpine species number but two. Yet the two species are equally numerous—a fact showing powerfully how one animal, despite disparity of numbers, may equal in vitality an apparently more prolific race. For the two young of the alpine salamander, when born, are large and active, have passed completely through their development, and possess strong acrid skin-secretions ; whilst those of the spotted species are comparatively helpless when born, and have not got rid of their gills. Hence the latter are subject to a greater mortality, and the proportion of adults to young is therefore relatively small. On no rational theory of nature could it be believed that a young newt was provided with gills, and that, thus furnished, it was destined to be developed *within its parent's body*. The two facts of the presence of gills and the development of the alpine salamander within the parent body are in utter opposition to each other. Further, we know that when taken from the parent body, long prior to their natural period of birth, and placed in water, the young of the black salamander live and breathe by their gills, as was undoubtedly the original habit of the species. Placed in water, the young beings live for weeks, and ultimately develop from their water life into land salamanders. But in this latter experiment, the full development of the young occurs weeks after the time when they would have been moving actively on the Alps, had they been left to their development within the parent frame. Thus we see, firstly, that the modern development of this animal is clearly acquired—even the curious habit of the two larvæ eating the other eggs clearly proves as much. And secondly, we again come face to face with a case of shortened and condensed development, favouring at once an early maturity and the increase of the race. Probably a rise of land, carrying these salamanders farther and farther from water, was the direct cause of the altered mode of life of the alpine salamander. We know that this new adaptation is of relatively ancient origin, for the gills of the salamander, placed in water, shrink by a natural and vital process of absorption, and not through mere drying and shrivelling as in the axolotl. The acquired process of gill-absorption has become, in other words, an inherited matter—has become part and parcel of the animal's constitution. As, therefore, their watery pools were left below by the rise of land, the salamanders would gradually acquire the habit of retaining the young within the body for more and more lengthened periods; and in due time, the present state of matters was evolved—including limitation of numbers and acceleration of development, along with the novel condition of utilising the remaining eggs as a food-supply.

An important and interesting feature in connection with the preceding cases of altered development, consists in the observation that the Mexican axolotl, apparently a mature form, was able to reproduce its species. It may perhaps prove a truer conception of the case if we regard the axolotl as a "permanent larval form," which has acquired the power of producing young, and which has therefore assumed the form, life, and constitution of a species. Analogy supplies us with a valuable series of parallel instances from the records of natural history science. The example in question, of a larva acquiring reproductive powers, is by no means singular or unique. We have seen that practically a pteropod or "Sea butterfly" (Fig. 152, B) is essentially the larval form of the gasteropod (A), which has had its immature character fixed, and which has acquired the power of producing young. Other cases of this peculiarity are readily found within the confines of the insect class, and in other divisions of the animal world. Thus, we know that the larva or maggot—itself an absolutely immature form—of a fly (*Cecidomyia*) (Fig. 164), produces other larva like itself, and these in turn produce others (*a*, *a*), which, finally becoming males and females, produce normal young through eggs. There is another insect (*Chironomus*) of which, as Grimm has shown, the chrysalis lays eggs; and we know of cases in which (as illustrated by the *Aphides* or plant-lice, and by the queen bees) perfect young may be produced by the one insect alone. So likewise the common Newt (*Triton cristatus*) of our ponds may, occasionally, when immature, produce young; and another species (*T. Alpestris*) has been seen to reproduce its kind when it was still in the tadpole stage. Amongst the zoophytes, such features are still more plainly marked. For a plant-like animal colony gives origin to jellyfishes, which swim freely in the sea, and later on produce eggs, from each of which a zoophyte in turn springs. These facts were formerly included under the head of "alternation of generations;" but under whatever name we denote the phenomena, the lesson they teach is uniform and clear. Such cases as these of the insect larva and the immature axolotls and newts producing young (contrary to the rule that only adult animals reproduce their species) prove to us that, if conditions be favourable, a young animal's development and constitution may be so modified and intensified, that it may, whilst still under its larval guise, produce young, and thus assume the likeness and functions of a new and distinct species. Such facts further impress the idea that the young being, equally with the adult, is liable to modification and change; and they therefore teach us that the starting-points of new species and races do not always lie within the domain of mature

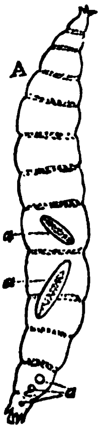


Fig. 164.
Cecidomyia.

life, but may take origin from stages in development prior to the full period of growth.

Given an ultimate independence of the young form, together with the power of producing beings resembling itself, and we may readily conjecture how a new and very different species or race may, in comparatively rapid fashion, originate from a well-known stock. Mr. Darwin gives as an example of this possibility, the case of the beetle Sitaris (Fig. 165 F), of which the first larvæ (A) are active and minute, and possess six legs, two long feelers, and four eyes. "These larvæ are hatched in the nests of bees; and when the male bees emerge from their burrows in the spring, which they do before the females, the larvæ spring on them, and afterwards crawl on to the females whilst paired with the males." Then ensues the laying of eggs on the surface of the honey in the cells by the female bees, the

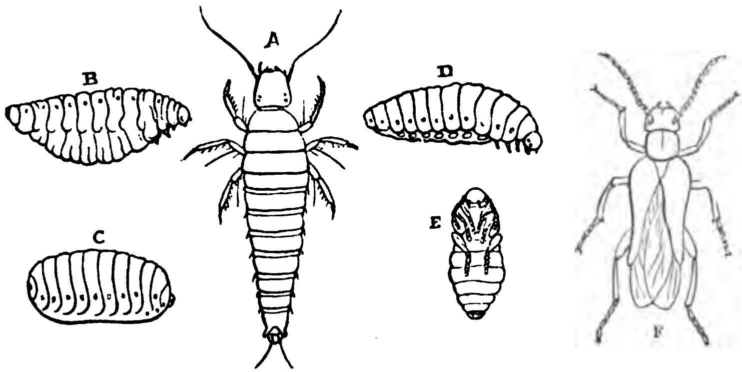


FIG. 165.—SITARIS AND ITS DEVELOPMENT.

Sitaris larvæ devouring the eggs. Then the latter undergo a metamorphosis. The eyes disappear, and the legs and feelers become rudimentary (B), whilst they feed on the honey. At this stage they more closely resemble ordinary insect larvæ (C, D, E), and after further transformation emerge as the perfect beetles (F). "Now," adds Mr. Darwin, "if an insect, undergoing transformations like those of the Sitaris, were to become the progenitor of a whole new class of insects, the course of development of the new class would be widely different from that of our existing insects; and the first larval stage certainly would not represent the former condition of any adult and ancient form." "We can see," adds Darwin, "how, by changes of structure in the young, in conformity with changed habits of life, together with inheritance at corresponding ages, animals might come to pass through stages of development perfectly distinct from the primordial condition of their adult progenitors." On this reasoning, the Axolotl's later history cannot be expected to coincide with that of the Amblystoma. It is a larval form, which, apparently arrested in development, has nevertheless, contrived to develop the lungs which mark the full growth of all amphibia, whilst it likewise retains the gills of early life. The relationship between the Axolotl and Amblystoma presents, besides, one of the most effective refutations of that common but ignorant remark that no one has yet adduced any proof of the direct transmutation of one species into another. In the case before us, not merely is the transformation one in which one *genus* of animals apparently becomes another, but the near relationship of two thoroughly distinct forms is thus proved to lie within the province of exact zoological observation.

It should be added that Dr. Weismann, of Freiburg, who has devoted much attention to the metamorphosis of the Axolotl, maintains that the case in question is one, not of sudden advance in a species, but of *reversion* to a lower stage. He believes that "those Amblystomas which have been developed in captivity in certain instances from *Siredon Mexicanus* (*S. pisciformis*), as well as from the Paris Axolotls, are not progressive but reversion forms. "I believe," concludes Dr. Weismann, "that the Axolotls which now inhabit the Mexican lakes were Amblystomas at a former geological (or better, zoological) epoch, but that owing to changes in their conditions of life, they have reverted to the earlier perennibranchiate (permanently-gilled) stage." One of the most interesting facts which lend support to this view of the backward development of the Axolotl is the discovery that the Axolotls possess a rudimentary *intermaxillary gland* furnishing a glutinous secretion, and which serves to aid the capture of insect-prey. Now, as this gland exists in a perfect shape in all land amphibians, but is absent in gill-possessing forms, its presence in the gilled Axolotls would certainly seem to indicate that these animals retain the gland as a legacy from the higher or Amblystoma stage from which they are believed by Weismann to have descended and retrograded. In whatever light we regard the case of the Axolotl, the bare facts of its curious development remain unaltered. It seems justifiable enough, notwithstanding Dr. Weismann's opinion, to regard the Axolotl as a "permanent larval form," and as representing an arrest of the development of Amblystoma, producing a literally new race of animals able to reproduce their like, and thus evolving a new group of animals by an easily understood modification of an existent species. The presence of the "intermaxillary gland" may represent the initial stage or beginning of that gland's development in the Axolotl race, instead of a degeneration from the perfect gland of the Amblystoma. Inheritance alone, might account for the development of this structure. But, indeed, whether we adopt Dr. Weismann's view of the Axolotl as a case of reversion from Amblystoma to its lower stage, or whether we regard the Axolotl races as representing larval forms permanently settled to form a distinct race and species, the influence of surroundings in evolving new forms of life receives an apt illustration. Arrest of development, an altered way of life, change of surroundings, and allied conditions, are seen to operate powerfully on animals and plants; and are found to effect exactly those changes in the constitution of the living world which evolution postulates, and which meet the biologist at every turn.

One typical case of similarity in early development, as suggestive of a near or common origin, from the group of birds, may merit mention in the present chapter. Mr. A. R. Wallace points out in an interesting fashion how the humming-birds (Fig. 166) of the New World, placed of old side by side with the Old-World sun-birds (Fig. 168), were, in 1850, separated from the latter forms and placed by Prince Lucien Bonaparte near the swifts (Fig. 167) in his system of classification. That this arrangement was correct—that is, was one based upon natural affinities, and not merely upon superficial resemblance—is easily provable. Thus the breast-bone of a humming-bird and that of a swift are marvellously like. It is not notched behind in either bird, whilst this bone in the sun-bird bears two depressions. In the colour and number of the eggs, swifts and humming-birds agree, and they also present close resemblances in the arrangement of their feathers. Both have ten tail feathers and sixteen true quill feathers; and in both the first quill is longest. But whilst the bill of a swift is short, broad, and flat, the gape wide, and the tongue flat, the humming-birds have a long, slender, cylindrical bill, and a tubular tongue, which can be protruded to a great extent, and which is used for drinking up the nectar of flowers. We shall allow Mr. Wallace to tell us of the striking resemblance between these two groups of birds, revealed by a study of the humming-bird at an early stage of growth. "When on the Amazon," says Mr. Wallace, "I once had a nest brought me containing two little unfledged humming-birds, apparently not long hatched. Their beaks were not at all like those of their parents, but short, triangular, and broad at the base—just the form

FIG. 166.—HUMMING-BIRD.

of the beak of a swallow or swift slightly lengthened. Thinking (erroneously) that the young birds were fed by their parents on honey, I tried to feed them with a syrup made of honey and water;

FIG. 167.—SWIFTS.

but though they kept their mouths constantly open, as if ravenously hungry, they would not swallow the liquid, but threw it out again, and sometimes nearly choked themselves in the effort. At length I caught some minute flies, and on dropping one of these into the open mouth it instantly closed, the fly was gulped down, and the mouth opened again for more: and each took in this way fifteen or twenty little flies in succession before it was satisfied. They lived thus three or four days, but required more constant care than I could give them. These little birds were in the swift stage;

FIG. 168.—SUN-BIRD.

they were pure insect-eaters, with a bill and mouth adapted for insect-eating only."

Such an interesting recital once again illustrates the maxim, that the likeness between living beings, imperceptible in the adult stage, may yet be plainly enough apparent in the earlier phases of development. As with the crustaceans, where we find a shrimp and a barnacle, utterly unlike as adults, beginning life under an essentially similar guise, so with the swifts and humming-birds — their likenesses, masked by differences in habits of life, are nevertheless traceable without difficulty in the young state. Mr. Wallace especially reminds us that certain of the sun-birds themselves, resemble the humming-birds in respect of their long bills and tubular tongue, adapted, like those of the latter birds, to feed upon flower juices and upon the insects that infest flowers. He emphasises the need for distinguishing clearly between characters or likenesses which are "structural"—that is, are part and parcel of an animal's being—and those that are purely "adaptive"—that is, arise from a similar mode of life, independently of the origin of the species. The former are transmitted from ancestors; the latter are the products of recent modification. The former indicate the true nature of the animal, because they are part of its inheritance; the latter often suggest false resemblances due to similarity of habits and not to community of origin. Thus, whilst the humming-birds and swifts possess structural and inherited likenesses, the former and sun-birds are related only through similar adaptive characters. The skull of a cuttlefish, to select another example, is comparable in its functions to that of a low vertebrate animal, but on no theory of nature are these two groups connected together. They have arisen, like the similarities of sun-birds and humming-birds, entirely independently, in respect probably of similar conditions, and not of inheritance from a common ancestor. The inherited characters which mark real resemblances are not, as we have seen, always apparent; and the adaptive characters through which the life of the species is carried on may entirely mask and conceal them. As Mr. Wallace puts it, we arrive at "the seeming paradox, that the *less* of direct use is apparent in any peculiarity of structure, the *greater* is its value in indicating true, though perhaps remote, affinities; while any peculiarity of an organ which seems essential to its possessor's well-being is often of very little value in indicating its affinity for (to) other creatures." Thus we are led to the conclusion, favoured again by development and its lessons, that the humming-birds "are essentially swifts—profoundly modified, it is true, for an aërial and flower-haunting existence—but still bearing in many important peculiarities of structure the unmistakable evidences of a common origin."

XII.

THE EVIDENCE FROM THE LIFE-HISTORIES OF INSECTS.

WHEN the development of an animal or plant is duly studied, one or two chief aspects of such a subject fail to be considered by the biologist. Either the young organism has been converted directly into the likeness of its parent, or it has assumed the parental form indirectly and through a series of transformations more or less distinctly marked. In other words, the young form has emerged upon the stage of life in the guise of its parent, or it has appeared first in a shape and under an appearance not recognisable as belonging to the race it has sprung from. In the latter case, changes of greater or less extent convert the young being into the likeness of its progenitors; and when such transformations occur in the life-history of an animal or plant, it is said to undergo "metamorphosis." Every one, for instance, knows that the butterflies of the garden do not emerge from the egg as winged insects, whilst common information is able to assert that they pass through the *larval* or "grub" stage and also through the *chrysalis* form before becoming the perfect insects. So, also, the flies begin their life as maggots; and the bees and beetles, with other insects, exhibit like stages to the butterflies in the course of their development. Furthermore, a frog, as we have seen, practically begins life as a fish, breathing first by external and then by internal gills. Sooner or later, however, limbs are developed; the gills are replaced by lungs; the tail disappears; and the tailless condition of the frog race is finally assumed with its emergence upon the land. Insects and frogs—not to speak of other animals, such as crustaceans, whose history has been already discussed in a previous chapter—are therefore said to undergo "metamorphosis."

Sundry questions not unnaturally rise in the mind which attentively considers such phenomena in the animal world. Firstly, there is the plain question, "Why do some animals undergo metamorphosis and others not?" Then, secondly, may be asked, "What is the meaning of metamorphosis?" or more primarily, "Can any meaning be assigned to this process?" As we have frequently had occasion to point out, such questions receive no aid or solution from that philosophy which maintains, as an article of unquestioning faith, that the living belongings of this world came forth fashioned in all their excellence—or, it may be added, in all their frequent and apparent imperfections—at the behest of some sudden creative fiat. There is no need to assume development at all on this hypothesis of things, which for the man of science has been slain long ago; though traces of its influence are not unknown in regions removed from the active currents and tides of culture. On the reverse side of matters, stands the theory broadly denominated "evolution," which, seeing the promise of reading a past and progressive history in the developments which pass in panoramic review before our eyes to-day, asserts that a law of progress has guided and still guides life's courses and ways. On this theory we can understand why development takes place—namely, because it is a law of life that the progress and growth of the race should be represented in, and carried out through, its individual histories. And we can also conceive why development should run in the grooves marked out so conspicuously in many life-histories, such as those of insects and crustaceans. This latter fact is explicable when it is repeated that we see in an animal's early growth, the lines and stages along which the development of its race has passed. By the very idea of evolution we expect variety and change to be represented in the development of living beings; for such change is the one great condition which has made this universe what it is. Agreeing as to the main reasons for development and its ways, we should find little difficulty in comprehending how these ways and paths have been followed. As we have already impressed upon the reader, the picture is not always clearly limned, and its outlines are often meagre enough. Still, what we do see and know of its form, convinces us of the correctness of the broad deductions of evolution; which deductions being scorned and denied, leave the whole course of nature a tissue of inexplicable absurdities.

In the present instance, dealing with the meanings of metamorphosis, we intend to direct attention to certain details which, for lack of space, have been omitted in previous chapters, and which, dealing with matters of special interest to the student of evolution, may, logically enough, claim attention in a separate section. Such subjects as the general nature of "metamorphosis," and how that process is modified by surroundings and other circumstances, as well as the narration of some life-histories which illustrate very aptly the general conclusions of evolution, may therefore fitly engage our consideration in the course of our developmental studies.

Firstly, then, the general question of "metamorphosis" demands notice. Whilst it is perfectly true that, broadly speaking, only such animals as insects, crustaceans, and frogs—exhibiting very marked and apparent change of form in passing from the young to the adult stage—may be said to undergo "metamorphosis," it would be far more logical, because more true, to assert that the histories of all living beings, without exception, illustrate the process in question. This remark has been made in reference to the developments we have already studied. For example, there is not, after all, such an immense difference between the development of an insect and that of a fish—or, for that matter, between that of the frog and of man himself—when the facts of development are fairly faced and duly understood. No animal or plant is suddenly transformed into the perfect likeness of its parent. On the contrary, it has not merely to grow, but it has to be formed from that which is formless; to become organised by the development of that which has no structure at all; and to advance along lines of development during which it successively assumes a transient likeness to the forms of other and lower beings. Thus a quadruped, whilst undergoing development within its parent's body, in reality passes through as strange and startling a metamorphosis as does a frog outside its parent's body, and external to its egg likewise. A quadruped is really at first like a fish and reptile. So alike are the young of all vertebrates in their early stages, that recognition of the nature of any particular form may be an impossibility. "Metamorphosis" thus occurs in quadrupeds as in frogs; in snails and oysters as in insects. The great and prevailing difference simply exists in the fact that the insect or frog leaves the egg in an imperfectly developed condition and at an early stage of its career, passing the remainder of its development as an independent being. In the quadruped or fish, or in the bird and reptile, the young animal does not quit the parent body or egg at such an early period, but remains within its primitive shelter to undergo its full development— or at any rate to emerge upon the world of active life tolerably well prepared for the struggle of living and being. Even amongst the quadrupeds, as in well-nigh every other group of animals, and as in the plant world likewise, there may be great differences in the degree and stage of perfection at which the young organism is ushered into active or independent existence. No better instance of this could be found than in the case of the kangaroos and their allies, in which, as lower quadrupeds, internal development ceases at a very early period compared with that at which higher quadrupeds are born. The newly born young of a kangaroo, which, when full grown, stands 6 or 7 feet high, measures about one inch in length at birth (Fig. 169), and resembles a little red worm much more nearly than a kangaroo. At birth it is transferred to the characteristic "pouch" of the mother, wherein for weeks it is protected and nourished by the milk secretion. If we consider the effects of growth on such an organism, we may well feel assured that a "metamorphosis" of very complete kind must be required to transform the imperfect and feeble being just described,

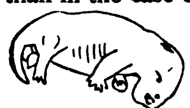


FIG. 169. YOUNG KANGAROO.

into the giant quadruped which takes its leap of twenty feet with the utmost ease. So, also, we find in the development of birds well-nigh infinite variety in the stage of perfection at which the young animal is thrown upon its own resources. Of old, naturalists were wont to divide the birds into those which could run about and forage for themselves immediately on leaving the egg, and those which, as mere fledglings, required parental care and attention for a longer or shorter period after bursting the shell. A young chicken is a much more independent being than, say, an infant thrush; and numerous other comparisons might similarly be instituted, with a like result of showing variations in the development of even the animals of a single class.

It seems, therefore, correct to say that the term "metamorphosis" is one of very considerable latitude, and one admitting, in fact, of no rigid definition at all. At the best its value is merely relative, and those animals may be regarded as really most "metamorphic," so to speak, which leave the egg in an immature state, and which, through circumstances which it is our business to trace in this chapter, have to pass through a definite or well-marked set of changes in form, shape, and often of size also, before assuming the likeness of the parental form. If we reflect that every living being springs from a mere speck of protoplasm, devoid of all structure, which we call "germ" or "egg," and which contains the potentialities of becoming what its parent now is; or if we further consider that from this speck of albumen there is developed in a few days, as in the case of the chicken, a creature rejoicing in the possession of a complex system of bone, muscle, sinew, brain, nerve, and sense organs—we may well feel inclined to consider such a transformation and development as thorough an example of "metamorphosis" as, and as a far higher development than, that of the insect which attracts our notice simply because it is more evident to our eyes. Another striking proof that "metamorphosis" must be, after all, a comparative term, lies in a knowledge of the fact insisted on and illustrated in a previous chapter—namely, that the eggs of all animals, from sponge to man, pass through the same stages up to and including a given point, at which each group branches off, so to speak, on its own pathway towards adult and specific perfection. Thus, why one animal undergoes those changes of form we see in the insect, and why another does not, are circumstances—to come to details—depending, firstly, on the size of the egg from which it is developed, and concurrently on the amount of nourishment the egg contains; and, secondly, upon the varying circumstances and surroundings of its life, as well as on the life and history of its race, as temporarily represented by its parent. Thus a large-sized egg, with a big yolk, will, *cæteris paribus*, produce an animal in a higher and more perfect stage of development than a small egg, in which no provision exists for the nutrition of the embryo. So much, indeed, may safely be predicted of the causes which retard or favour an early escape from the egg. In the latter case, of course, let us bear in mind that the young will not resemble the parent animal, and we naturally expect to behold changes of form or "metamorphosis" in its further development, and ere it attains to the parent size and likeness.

But we must not neglect to note an equally important cause of alteration in form, which, acting subsequently to the escape of the immature animal from the egg, will direct its footsteps in different channels, and clothe its form with varied guises. The surroundings of an animal's life necessarily affect that animal, and in time its race, viewing individual and race as consisting each of an adult being and beings. This much is the plainest of plain truths. But it is equally true that surroundings and varying conditions

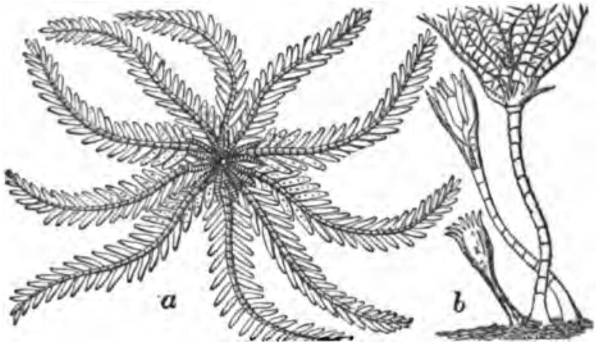


FIG. 170.—THE ROSY FEATHER-STAR'S DEVELOPMENT.
a, adult starfish; *b*, young stalked forms.

of life must also affect the *young* stages of animal existence. Even more marked and powerful must be the effect of outward conditions on the young organism, whose frame and constitution, not yet fully formed, are infinitely more plastic and facile than those of the adult. All we know of the effects of environments on living beings, teaches us this lesson. We know something of the effects of heat and cold, of a change of medium, and of numerous other circumstances which materially alter the development of both animals and plants. Natural-history records teem with examples of these facts. A young rosy feather-star (*Antedon*, Fig. 170) may be hurried through its larval state, and may be made to gallop post-haste through its "metamorphosis," if it be supplied with pure sea water. If, on the other hand, such a larva be kept at a low temperature, and in water not frequently changed, and consequently on a more meagre dietary, it will delay in its larval progress. Its development may not merely be greatly protracted and prolonged, but it will attain to a higher stage of independent development than before. So also with many insect larvæ, and so with zoophytes. The effects of varying conditions on the young and developing animal are plainly traceable. It remains for us to discover what light such reflections throw on some well-marked and familiar cases of metamorphosis around us.

The insect world teems with examples of "metamorphosis" at once striking and interesting. It also, however, illustrates a previous remark, that in one and the same class we may find great variations in development and "metamorphosis." For instance, we may find no metamorphosis at all in some insects. The lice, the bird-lice, and the spring-tails (*Thysanura*) thus come from the egg resembling in every respect, save in size, the perfect insects. They simply cast or shed their skin at each successive stage of growth, but no change of form is represented in their development. So also with many insects of higher rank. A kind of day-fly (*Chloëon*, Fig. 171) is described by Sir John Lubbock as undergoing no fewer than twenty moultings of its skin during its "metamorphosis," which is not, however, of marked or distinct character, since the organs of the young animal are simply and gradually changed into those of the adult insect. Even in insects which undergo a much more typical metamorphosis than the day-flies, the gradual conversion of the larval parts into the organs of the adult may be witnessed. A young cricket (Fig. 176) becomes the adult very gradually, and the days of its infancy are not markedly separated from those of its youth, nor are these latter in turn sharply defined from the period of adult life.

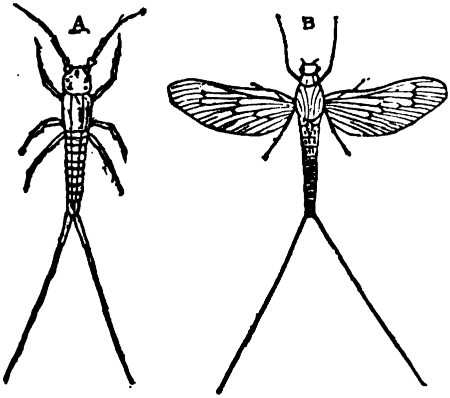


FIG. 171. CHLOËON.
A, larva; B, perfect insect.

Turning, however, to actual details, we find a butterfly (Fig. 172), fly, and beetle respectively to exhibit the so-called "perfect" form of metamorphosis. Each begins life—that is, comes from the egg, after the preliminary stages common to all eggs—as a grub, caterpillar, or *larva* (*a*), which spends the first part of its existence in the guise of a worm, eating voraciously and increasing, as a rule, many times its original size in bulk. Next this voracious grub settles down and becomes the *chrysalis*, or *pupa*. Here, quiescence is the order of the day. Sometimes within the larval skin, or it may be (as in butterflies and moths) within a special case or cocoon (*b*), the chrysalis passes its existence, which, however quiet and apparently unimportant, externally viewed, is nevertheless marked by a wonderful activity inside. There the elements and nutrient parts of the larva, accumulated during its season of epicurean enjoyment, may be practically broken down, and rebuilt to form the body of the perfect insect, as in some flies, or more gradually changed into the adult organs, as in the butterflies. As Sir John Lubbock succinctly puts it, "the change from the caterpillar to the chrysalis, and from this to the butterfly, is in reality less rapid than might at first sight be supposed; the internal organs are metamorphosed very gradually, and even the sudden and striking change in external form (from the chrysalis to the perfect insect) is

FIG. 172.—METAMORPHOSIS OF SWALLOW-TAILED BUTTERFLY.
a, larva; *b*, chrysalis; *c*, imago, or perfect insect.

very deceptive, consisting merely of a throwing-off of the outer skin —the drawing aside, as it were, of a curtain, and the revelation of a form which, far from being new, has been in preparation for days, sometimes even for months."

In the metamorphosis of certain of the flies—*e.g.* the flesh-flies—the changes are in reality much more sweeping than in the butterflies, although perhaps less apparent than in these brilliant members of the class. The body of the maggot or larval fly contains, when it leaves the egg, a number of curious rounded structures named *imaginal discs.* Some twelve of these are placed in the young insect's chest-region—four in each segment—and two are situated in the front part of the maggot's body. No change is perceptible in these discs during the caterpillar or larval stage of the fly's life; but when the maggot encloses itself within the last of its skins, which serves it as a chrysalis case or cocoon, the discs begin to undergo a marked development. Each of the lower discs placed in the insect's chest, develops a leg and half of the segment of the body bearing the leg. The upper discs of the joint give origin to the upper halves of the segment and to the wings or their representatives; and the two foremost discs are responsible for the development of the head and mouth parts of the perfect fly. As development proceeds, we find a complete physiological break-down of the chest and head organs of the maggot to be represented. A literally new creature (as to chest and head) is produced and built up from the imaginal discs; the tail or abdomen of the fly consisting, however, of a mere extension and growth of that of the maggot. There is thus witnessed in the development of the fly a much more complete series of changes than in the metamorphosis of a butterfly, and this notwithstanding the fact that the changes undergone by the latter appear to be of more sweeping character than those exhibited by the former insect. Let us bear in mind also the fact, already noted, that the developmental changes in insects may be reduced to a minimum, in respect that many lower insects do not undergo any metamorphosis at all. Even in the cockroach (Fig. 173)—belonging to the *Orthoptera*, or grasshopper and locust group—an insect familiar enough to warrant its special mention in the present instance, the young possess eyes, feelers, jaws, and legs before they are hatched. They further leave the egg as minute but active insects, whose organs are really moulded upon the type of those which the perfect cockroach possesses. The young insect then undergoes seven moultings or changes of skin. Its first moult occurs when it leaves the egg, and its second takes place about a month afterwards. This second moult being performed, no further shedding of skin takes place until a year afterwards; and as but an annual moult subsequently occurs, the insect does not attain maturity till its fifth summer. Thus, in the cockroach, "metamor-

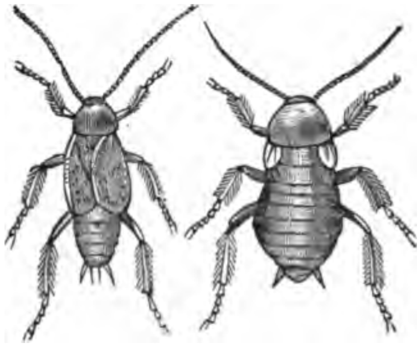


FIG. 173.—COCKROACHES.
(The left-hand figure represents the male; the female, with rudimentary wings, is represented on the right.)

phosis," in the sense in which that term is used as regards the butterfly, does not occur at all. The male insect, it is true, develops wings at a late stage of development, but there is no chrysalis-stage and no quiescence, as in the butterfly or beetle.

How, then, it may be asked, are the differences between the metamorphoses of insects to be accounted for? On the theory that the development of the individual recapitulates the evolution of the race, it may be asked, do not the facts and differences of metamorphosis in insects seem to present very grave difficulties? There is not that general likeness seen, for instance, in the young of different Crustaceans, nor the similarity in development witnessed in the Echinoderms or starfish group. These apparent difficulties, however, become greatly lessened, or may disappear entirely, if we bear in mind the fact, already insisted on, that as adult animals vary and alter, and so evolve new species, so the young and developing forms are even more subject to modification whilst in the process of growth. In other words, let us clearly understand that the changes an animal or plant may undergo are two in number. Firstly, there are *developmental* changes, or those we have been tracing in previous papers, which belong to the animal as part of its inheritance, and which cause it to travel along the line of its ancestry towards the likeness of its parent. Then there are, secondly, changes which must be named *adaptive*; which arise from the operation of surrounding circumstances—heat, cold, food, &c.—and from the action upon the living being of external forces. These latter are changes "adapting" it to, it may be, new ways and walks of life, differing from those of its parents and ancestors, and remodelling its frame in a novel guise. The young insect, in truth, may be described as living between two sets of forces or conditions. One set may be named "centripetal," or centre-seeking, for want of a more descriptive term. These are developmental changes which tie it to its type and which cause it to travel along the beaten track of its race. Then there are the "centrifugal" or adaptive forces, which tend to make its development erratic, which may cause it to fly off at a tangent, so to speak, from its normal way of growth, and which necessarily cause it to differ materially from its type and race. Says Darwin, in speaking of development at large: "Many insects, and especially certain crustaceans, show us what wonderful changes of structure can be effected during development." A little later he proceeds to remark that, whilst similar organs in the young of different animals "often have no direct relation to their conditions of existence" (*e.g.* the gill arches of a quadruped, a bird, a frog, and a fish), the case is "different when an animal, during any part of its embryonic career, is active and has to provide for itself. The period of activity," says Darwin, "may come on earlier or later in life; but whenever it comes on, the adaptation of the larva to its conditions of life is just as perfect and as beautiful as in the adult animal. In how important a manner this has acted, has recently been well shown by Sir J. Lubbock in his remarks on the close similarity of the larvæ of some insects belonging to very different orders, and on the dissimilarity of the larvæ of other insects within the same order, according to their habits of life. Owing to such adaptations," continues Mr. Darwin, "the similarity of the larvæ of allied animals is sometimes greatly obscured, especially when there is a division of labour during the different stages of development, as when the same larva has during one stage to search for food and during another stage has to search for a place of attachment. Cases can even be given of the larvæ of allied species, or groups of species, differing more from each other than do the adults."

Now, these are weighty words, because they sum up the reasons why, admitting a general similarity of early development in insects, we should find so much variety in the later development we name "metamorphosis." They direct our attention to the fact that adult life is not the only period when changes in the constitution and form of the living being occur; and they emphasise very clearly the further fact that to changes occurring in the young stages of an animal are due many of the most characteristic and curious details of animal form and growth. If we wish for examples of unlike larvæ of insects belonging to the same order, we may find any number of such instances amongst the beetles. Some beetle larvæ are footless grubs; others are well provided with legs; some have feelers, others want feelers; and variations in form are very numerous indeed. Or among the *Neuroptera*, an order including the dragon-flies (Fig. 174), day-flies, white ants or termites, and a host of other insects, the larvæ differ somewhat; but the pupæ or chrysalides are exceedingly varied, some being quiescent, others active, and others again being

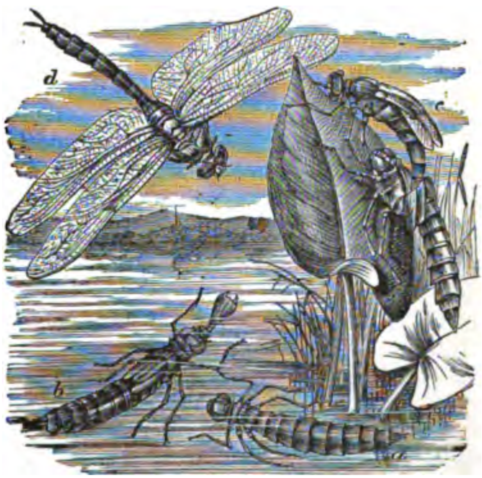


FIG. 174.—DRAGON-FLY AND ITS METAMORPHOSIS.
a, larva; *b*, pupa; *c*, *d*, perfect insects.

at first motionless and afterwards moving about. It is not difficult, moreover, to show how very perfectly adapted to varied ways of life different larvæ have become. The worm-like form of those larvæ which live parasitically in the interior of other animals, or in plants, may attract our notice as an adaptive feature. Such forms are well represented in the young of the botflies, which pass their existence either within the digestive system of the horse or within the tumours they form on the backs of cattle. Witness, on the other hand, the strong-jawed, weak-legged larvæ which burrow in wood; or the well-developed legs of those which feed on leaves or which forage for animal matter. Compare with these features, again, the degradation and modification causing those larvæ which are fed by parents or "nurses" (*e.g.* young ants and bees) in the cells of their hives, to become fleshy, footless, inactive grubs; whilst, as a feature of highest interest, it may be noted that the bee grubs do possess at one period of development rudiments of legs, which, however, soon disappear. The fact, as Sir J. Lubbock remarks, "seems to show, not, indeed, that the larvæ of bees were ever hexapod (or six-legged), but that bees are descended from ancestors which had hexapod larvæ, and that the present apod (or footless) condition of these larvæ is not original, but results from their mode of life." The changes which have converted bee larvæ into footless grubs are, in other words, not developmental, but adaptive.

To follow out in detail the full history of insect metamorphosis would be a task lying far beyond the scope or limits of the present chapter, in which other details of varied developments have yet to be noted. The key-note of metamorphosis, and its explanation, is struck when the great fact of modification of the young, as well as of the adult, becomes patent to us. Anything which may be said further regarding metamorphosis, is in reality an enlargement and illustration of this thought. But we may, nevertheless, glance briefly at one or two points in connection with the history of insects by way of rendering clear the probable lines along which the production and evolution of metamorphosis has taken place. We have seen that the changes which an insect undergoes have reference, not so much to its future form or adult state, as to its more immediate wants and to the exigencies of its life when undergoing development. We have noted likewise that the insect, like every other animal, is developed and exists between two sets of conditions—namely, those which tend to keep it in its ancestral grooves, and those which tend to alter its constitution through the influence of new surroundings. Insects are known, further, to pass through every gradation of development; from slight change, limited to the moulting of the skin, to that which is illustrated by the dissolution of the larval body and the rebuilding of its frame to form the adult. Is there any information at hand, it may next be asked, which affords us any clue as to the original stock from which the insect type, in all its fulness and variety of form, has been derived? Assuming it to be a probable and consistent view of the case that the mere metamorphosis of insects is a matter which, as already explained, is adaptive and secondary rather than original, what of the parent stock? and what does the study of metamorphosis, closely viewed, teach us concerning that root form? How is it, we may lawfully inquire, that such characteristic features of an insect as its wings and its mouth-parts were evolved?

It may facilitate our comprehension of these matters if we firstly begin with wings and mouth, and finally direct attention to the probable origin of insects as a whole. There are two main types of mouth in insects—one illustrated by the butterflies and moths, in which all the organs are modified to serve as a suctorial apparatus for drinking up the nectar of flowers; and the other, typically represented in the beetles, where we find a high development of jaws adapted for mastication and prehension. Intermediate between the suctorial and the biting mouth, we find that of the bees and wasps, where jaws coexist with a tongue or proboscis. It may be said, however, that there is but one type of insect mouth, all the forms of this apparatus being merely modifications of the one type form. Very curious, however, are some of the changes which the mouth-parts undergo in the course of their development. For example, a caterpillar begins life as a biting insect, and is provided with powerful jaws—a fact which its ravages on leaves fully endorse. Ultimately, as the butterfly, its mouth is wholly suctorial; its chief organ being the long *antlia*, or *proboscis*, used for drinking up the flower juices, and in reality corresponding with the second pair of jaws in a beetle. There is a clear aid to our thoughts on this matter, when we discover that the varied mouths of insects are thus all really built up on one type. Our difficulty, therefore, is not that of accounting for the origin of new structures, so much as that of saying how one phase of an organ becomes modelled to form another phase of the same type.

An acquaintance with the broad facts of natural-history study reveals modifications quite as wonderful in other groups of living beings. It is even more curious to find the arm of man, the wing of the bird, the fore leg of the horse, and the wing of the bat built up on the same type, than to discover a change of type in one and the same insect's mouth in the course of development. If we go back to insects in which the mouth-parts are simple and possess jaws of elementary pattern, we may as readily conceive of these jaws becoming altered to form suctorial organs, as of the same type of limb being modified in one case to walk and in another to fly. The alteration of ways of life and living, and changes in food, would be sufficient causes for the modification, which, proceeding slowly and gradually, would in time become naturally repeated in the life-history of the race. Or, further, as Sir John Lubbock suggests, the young insect might have access to, or even be compelled to eat, different kinds of food at different periods of its existence. Every variation of mouth has a reference, like the form of larva, to the life and food of its possessor. Is there, after all, any great difficulty in conceiving that the varying forces and conditions which include in their work the production of very different larvæ in even a single group of insects, should have likewise altered and transformed the mouth-parts of these animals? In truth, alteration of mouth is simply a part of a transformation which becomes the more wonderful as our view of its scope enlarges. Nor does the consideration of the origin of the insect mouth fail to lead us incidentally to discuss the meaning of the pupa or chrysalis stage. "Granting, then," says Sir John Lubbock, in speaking of the modification of the biting to form the suctorial mouth, "the transition from the one condition to the other, this would no doubt take place contemporaneously with a change of skin. At such times we know that, even when there is no change in form, the softness of the organs temporarily precludes the insect from feeding for a time, as, for instance, in the case of caterpillars. If, however, any considerable change were evolved, this period of fasting must be prolonged, and would lead to the existence of a third condition, that of the pupa, intermediate between the other two. Since the acquisition of wings is a more conspicuous change than any relating to the mouth, we are apt to

FIG. 175.—GRASSHOPPER.

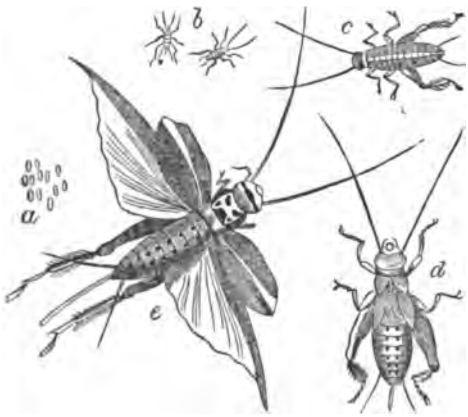


FIG. 176.—CRICKET.
a, eggs; *b*, arvæ (natural size); *c*, magnified; *d*, chrysalis; *e*, perfect insect.

associate with it the existence of a pupa state; but the case of the Orthoptera (cricket, Fig. 176, or grasshoppers, Fig. 175, &c.) is sufficient proof that the development of wings is perfectly compatible with permanent activity; the necessity for prolonged rest is in reality much more intimately connected with the change in the constitution of the mouth, although in many cases, no doubt, this is accompanied by changes in the legs and in the internal organisation." The same authority expresses the opinion that, whilst the biting mouth can be modified to form the suctorial—a change witnessed in every developing moth and butterfly—the originally biting mouth of the beetle could not have been directly modified, contrariwise, to form a sucking apparatus, "because the intermediate stages would necessarily be injurious." More probable is it that both types have sprung from some more primary form of mouth, which, partaking of the character of neither, has been therefore capable of modification in either direction, "by gradual change, without loss of utility." That such a form of mouth, united to a body of equally convenient

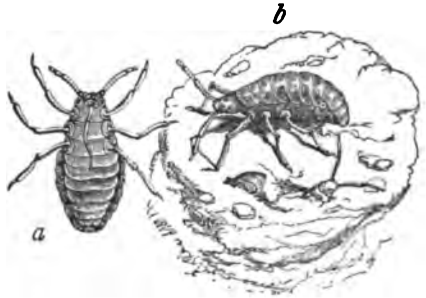


FIG. 177.—PLANT LICE.
a, wingless insect; *b*, wingless insect.

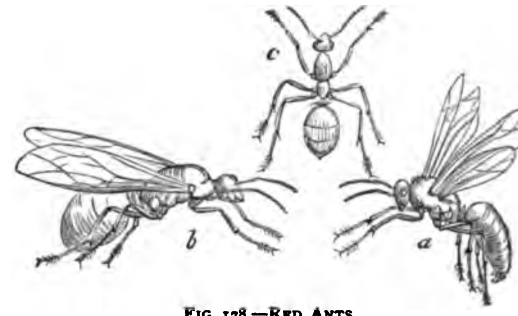


FIG. 178.—RED ANTS.
a, male, and *b*, female (both winged); *c*, neuter.

primitiveness, is to be found still represented in the ranks of living insects, we shall shortly discover. Meanwhile the question of wings awaits a brief notice.

The nature of an insect's wing, discussed in reply to the question "What is it?" throws some light on the question of its origin. The physiology or use of a wing is, of course, to serve as an organ of flight. But the use or function of an organ may be, and often is, a secondary and adaptive matter, and may be very far from revealing the original condition of the structure in question. Authority in matters entomological, assures us that the wings, as appendages of the insect's body, are in reality parts of the animal's breathing system. They contain branches of the breathing tubes, and expansions of the blood-vessels likewise. "Hence," says Packard, "the aëration of the blood is carried on in the wings, and thus they serve the double purpose of lungs and organs of flight." But we must note that many insects are absolutely wingless. The lice, spring-tails, and fleas, and even the plant lice (Fig. 177) and neuter ants (Fig. 178, *c*), belonging to winged groups, are destitute of these organs. No doubt the wingless condition in the latter cases is to be explained on the theory of disuse causing the disappearance of these organs. But the most primitive insects are without wings, and we may, therefore, reasonably conclude that wings are not original belongings but late developments of the race. Furthermore, many insects of relatively high rank, such as the crickets, grasshoppers, &c., quit the egg without wings, and this although they are extremely active in every respect. A wingless state is on all grounds, including the evidence of development, to be regarded as the original condition of the insect class. We have seen the intimate connection which exists between the wings and the breathing of insects. Of the two functions, breathing is, of course, much more primary and essential to life than flight. Hence we may well conclude that as many insects, especially the most primitive, breathe and live without wings, whilst others develop wings and utilise them for breathing as well as for flight, the

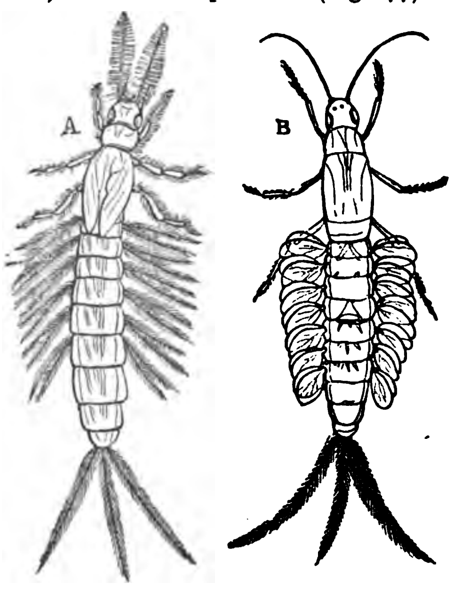


FIG. 179.—AQUATIC INSECT LARVÆ, SHOWING THE BREATHING GILLS.
A, Larva of *Ephemera* or Day-fly; B, Larva of *Cloe bioculata*.

breathing function, and not that of flying, was the first use to which the earliest insect wings were put.

The first beginnings of wings probably existed as we see the thin skin-folds of the water-living young (Fig. 179) of some insects to exist to-day—that is, as primitive organs adapted for breathing air from water (Fig. 179). One singular little water larva, that of *Chloëon* (Fig. 171), one of the *Ephemeridæ* or "day-flies," possesses side expansions for breathing, which are moved by muscles, as are the wings; and from what is known of other insect larvæ inhabiting water, it seems highly probable that a pair of these flat "gills" to each joint of the body (Fig. 179) may have originally been developed. The next stage in the evolution of the wing from this side gill—within which, be it noted, the breathing tubes branch out—would consist in these "gills" being employed as agents of aquatic flight—that is, flight under the water. In time, the hinder gills would alone be devoted to breathing, whilst those of the middle of the body, being the most advantageously placed for locomotion, would become the wings. Probably the first insect wings were used to propel their possessors under water. Such a state of matters is now seen in *Polynema natans* (Fig. 180), which Sir John Lubbock discovered in 1862. Thereafter, to movements under water would succeed movements on the surface, and as the muscular developments progressed, the beginnings of aërial flight would be simply a matter of time. The late acquirement of wings in the developing insect of to-day, is thus a fact not without its due significance. Such an event clearly enough shows us, firstly, that flight was a power superadded to insect locomotion long after the evolution of the race from some primitive wingless type; and secondly, that wing-power was evolved through the intermediate stage of gills still represented in the water-living larvæ (Fig. 179) of our day-flies and their near kith and kin.

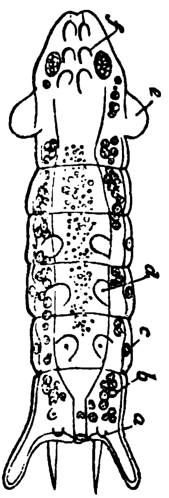


FIG. 180.—POLYNEMA. *a*, antennæ; *c*, rudiments of wings; *d*, rudiments of legs.

As Gegenbaur remarks, the wings correspond in nature with the gill-processes just described, "for they do not only agree with them in origin, but also in their connection with the body and structure." "It is quite clear," the same authority continues, "that we must suppose that the wings did not arise as such, but were developed from organs which had another function, such as the tracheal gills; I mean to say that such a supposition is necessary, for we cannot imagine that the wings functioned (or acted) as such in the lower stages of their development, and that they could have been developed by having such a function."

That this speculation is a highly probable one is proved by the curious fact that one insect (*Pteronarcys regalis*) belonging to the Orthoptera, inhabiting damp places, retains its gill-bearing organs throughout life. The mere possibility of the aquatic origin of insects is therefore placed beyond doubt by such an observation, whilst the fact that *Pteronarcys* belongs to the ancient order Orthoptera, shows its alliance with a primitive type of the insect class.

The consideration of the probable original or type form of the insect class now demands attention. The tyro in natural history knows that insects, along with spiders and scorpions, centipedes and crustaceans, form a great division of the animal world, to which the name of *Arthropoda* ("jointed-legged" animals) is given. The latter group in its turn forms a division of the great Articulate type, of which group the possession of a jointed body (seen equally well in the insect's body, in the centipede's frame, or in the lobster's tail) is a chief characteristic. Now, the origin of the Arthropoda from some lower and worm-like stock is not a matter which involves any very great draught upon the speculative faculty. From some such stock the tribes of spiders, insects, crustaceans, and centipedes have probably originated. There exists, indeed, a curious animal known as *Peripatus*, which is in many respects entitled to be considered as a primitive Arthropod. From some such form as *Peripatus*, it is not improbable that at least the insects, centipedes, and spiders were evolved. We have discussed in a previous chapter the nature of the form which has probably through its evolution and development given origin to the crustacean hosts and legions. This form is the *Nauplius*, which, in the development of highest and lowest crustaceans alike, reappears as the root and stock of the class, and whose modifications form the puzzles of the philosophical naturalist of modern times. Now, what is so clear in the case of the Crustacea is well-nigh as patent in the history of insects. We certainly do possess in existing groups of insects forms which appear to fulfil the conditions incidental to the purpose of serving as a generalised type from which insect evolution may have taken place. Such groups are those known as the *Thysanura*, or "tuft-tailed" insects, and the *Collembola* of Lubbock, both of which orders may be found on examination to present us with the natural root stock of higher insects. A brief inquiry into the characters of these latter insects may appropriately bring this chapter to a close.

Professor Huxley, in a recent manual of comparative anatomy, speaks of the cockroach as an "insect without metamorphosis"—a fact already noticed—and remarks upon the obvious difference which exists between such a form as a butterfly, with its resting chrysalis, and the young cockroach, active throughout its whole development. "It is obvious," continues Huxley, "that a metamorphosis in this sense (*e.g.* the butterfly or moth) is a secondary complication superinduced upon the direct and gradual process of development exhibited by such insects as the cockroach (Fig. 173)." It is also laid down as an axiom of zoology that insects which, like butterflies, undergo a complete metamorphosis (Fig. 172) are more differentiated and better specialised—in a word, are the products of a higher phase of evolution—than those which undergo no metamorphosis. So also we are duly warned that insects "which never possess wings are less differentiated or more embryonic than those which are winged. And, finally, insects with the parts of the mouth in the condition of ordinary gnathites (or jaws) are less differentiated than those in which such gnathites are changed in form and function or become confluent." Now, on this view of matters, a butterfly is bound to be regarded, as we have seen on the grounds of its development, as a highly modified insect, far removed from the primitive type. On the other hand, "the insects which in this view of their morphological relatives occupy the lowest position in the group, are the Collembola and Thysanura." To these we may perhaps add the true lice and bird-lice (Mallophaga), because these also undergo no metamorphosis and possess no wings.

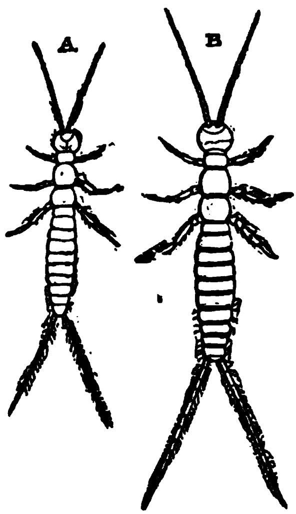


FIG. 181.—CAMPODEA.
A, larva ; B, perfect insect.

What, then, are these Collembola and Thysanura, in whose *personnel* and development we may expect to find the primitive form of the insect type? The Thysanura, of which the *Lepisma* and *Campodea* (Fig. 181) are good examples, are small insects, living in dark situations, such as amongst damp moss and under stones. The body is either hairy or (as in *Lepisma*) covered with minute scales, which constitute objects used for testing the defining powers of microscopes. On the whole, the Thysanura very closely resemble the young of the cockroach. The tail or abdomen is composed of some ten segments, and bears paired appendages, from seven to nine in number. They possess breathing tubes, but, as already remarked, want wings and exhibit no metamorphosis. The Collembola differ from the preceding group in possessing a tail consisting of six joints only, and a curious tube or sucker, by the viscid secretion of which they attach themselves to fixed objects.

Their popular name of "spring-tails," derived from the presence of appendages formed on a "spring and catch" principle, and by means of which they are enabled to take leaps of considerable extent, indicates another peculiarity of the group. Only in one genus of the Collembola, likewise, are breathing tubes found. The jaws or "gnathites" in Campodea and the Collembola are not very markedly developed. As Sir J. Lubbock remarks, the jaws "are far from strong, but still have some freedom of motion, and can be used for biting and chewing soft substances." Of these lower insects, the genus *Campodea* (Fig. 181, B) is particularly interesting, inasmuch as it seems to combine in its person all the primitive characters which give to its neighbours their extreme interest in the eyes of naturalists. Campodea, which occurs in loose damp earth, has an elongated cylindrical body, long and many-jointed antennæ, with paired appendages on the first seven joints of its tail, and long tail-appendages likewise. Now, if we compare the young or larva of Campodea (Fig. 181, A) with the adult (B), we find little or no difference save in size. Its whole organisation reminds us forcibly of the young stage in such insects as the cockroaches and other Orthoptera (Figs. 173, 176); whilst there are larvæ in other groups of insects to which Campodea and its neighbours bear a close resemblance. Furthermore, the larva (Fig. 171, A) of the day-fly (*Chloëon*), which possesses the gill appendages already referred to, is exceedingly like this Campodea, whose mouth-parts appear equally capable of further development to form the jaws of the beetle, or of modification to become the suctorial apparatus of the butterfly.

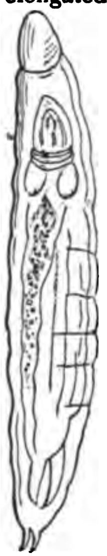


FIG. 182. LINDIA.

Thus, on all the grounds on which it is possible or necessary to look for resemblances between Campodea and the young of higher insects, such likenesses are discoverable. And the conclusion is thus rendered highly probable that existing insects have been evolved from an ancient Campodea-like stock—that is, from an animal form with a jointed body, three pairs of legs, weak mouth-parts, one pair of feelers, and a tail provided with jointed appendages. Hence a mental forecast is prepared to see this Campodea-form developing in one direction, through an insect like the young Chloëon (Fig. 171, A), or the water-larvæ (Fig. 179) already described, with their side "gills," into winged and higher races. Or in another direction, and through less modification perhaps, we may in our "mind's eye" behold Campodea growing in time into the stock whence the *Orthoptera*—our existing crickets (Fig. 176), grasshoppers (Fig. 175), and locusts—themselves a primitive group of insects, have sprung. Backwards, on the other hand, in the scale, retrograding from Campodea, we may even conceive of the stock from which that insect itself has sprung. Campodea within the egg must pass through the stages common to all animals at a like stage of development. There is a stage in the Arthropod type when the young of the insect or crustacean is little else than a footless, imperfectly developed worm. There is even a worm-like larva of an insect allied to the gnats, which corresponds to such a description; and such low insect-larvæ become in turn obviously related in form to certain low creatures allied to the worm kith and kin. One of these low forms (*Lindia*) is depicted in Fig. 182. This legless organism is related to the well-known "Bear-animalcules," and Rotifers, or Wheel-animalcules. Its jaws resemble those of the larval flies; it has a ringed body, and in other respects exhibits a close likeness to the young of many insects. Possibly, therefore, in some such primitive root, common to a whole host of animals, we may find the dim, ill-defined starting-point whence, led towards *Peripatus*, and by Campodea, the insect tribes have grown into the brilliance and aërial grace which mark their ranks to-day.

It may not be unprofitable, at the close of our investigation into insect history, to remind ourselves of the great problem which their development has lent its aid in part to solve. At the risk of apparently unnecessary repetition, let us keep in view that every such history, however its individual terms are to be accounted for, forms a link of greater or less importance in demonstrating the great law of evolution, modification, and adaptation as the true method whereby Nature has wrought out the endless variety of the children of life. Especially useful and important, moreover, is the history of the insect as illustrating the changes which the adaptation and modification of the young form may effect in the history of a species. So far from the chrysalis or pupa being a stage in the ancestry of the insects, we have seen that it represents merely a secondary and acquired phase of their development. As Fritz Müller has succinctly formulated it, "the historical record preserved in developmental history is gradually EFFACED as the development strikes into a constantly straighter course from the egg to the perfect animal, and it is frequently SOPHISTICATED by the struggle for existence which the free-living larvæ have to undergo." These words sum up the reason why insects in their metamorphoses exhibit all gradations and shades, from mere moulting of skin to complete change of form through a chrysalis state. Primarily they undergo a metamorphosis because they happen to leave the egg at a relatively early period of development; but they share "metamorphosis"—using the word in the broad sense—with every other living being. It is this plainly discerned series of changes which has chiefly given to the study of entomology its fascination in the past.

One may, however, well be regarded as enunciating a veritable truth when it is stated that the new light which evolution throws on the "why" and "how" a butterfly develops, and a Campodea remains inert, is likely to invest insects, and indeed all other forms of life, with an interest far surpassing that which past years could have imagined or conceived.

XIII.

THE EVIDENCE FROM THE CONSTITUTION OF COLONIAL OR COMPOUND ANIMALS.

AMONGST the many aspects in which the biologist is accustomed to view the universe of life, few possess a greater interest than that which deals with the nature of animal and plant personality, and with the structural philosophy of the living frame. It is not sufficient for the due investigation of living structures that the forms of animals and plants be compared, and their more obvious differences and peculiarities noted and recorded in scientific annals. Such details and such procedure suffice perfectly for the ordinary run and course of biological work, and form, no doubt, the source of the every-day knowledge on which natural-history science grows and progresses. But a higher era of scientific thought intervenes when philosophy, in its search after relationships and causes, steps forward to correlate and utilise the knowledge observation has acquired. The higher questions of cause and origin are not solved by observation alone. It requires and demands the power of placing facts in appropriate light and shade ere the mutual relations of these facts can be determined, and before their place in the *systema naturæ* can be definitely ascertained. Judged by this criterion and standard, there are some topics of biology which altogether belong to the region of the abstract and the transcendental. Patient industry may discover, for instance, that a crayfish within the egg repeats, as a stage in its development, the likeness of a form represented to-day by the adult state of some lower crustacean; but it requires philosophy of a transcendental kind to see what that fact means, and what such a discovery implies to the universe of life around. One may perfectly appreciate by ordinary observation that a horse walks on the single toe of each foot, and that its two "splint-bones" represent useless rudiments of other two toes; but it is through an exercise of abstract science alone that we can form the concept of a single-toed horse having arisen from a three-toed one; and from the latter phase of development extend a like thought to that of other living beings. The applications of philosophy to the facts of nature remind one strongly of the most singular and mysterious work of that nature in the production of the living thing itself. In the performance of that function, we require a certain quantity of the substance called "formative material" by the learned in biology, and "protoplasm" by the simple-minded amongst us. This material contains all that is required for the formation of the living frame in so far as the material of that frame is concerned. But in protoplasm alone, we do not find all that is demanded for the growth of the new being. We require, likewise, activity of some kind—potential or real, chemical, physical, or vital, or all three combined; and we depend upon this activity for the combination of the elements of our germ and for the power whereby that germ will in time blossom out into full fruition. So is it, in truth, with the application of knowledge, and with the evolution of the wisdom which arranges our knowledge in its due array. The knowledge we gain is, after all, in itself pure material, on which the potential power of philosophy must exert its influence ere the results of seeking and finding wisdom be fully appreciated. The evolution of a natural fact, or set of facts, to take its place in the array of knowledge we name a science, is therefore matter of higher development than that which merely discovers the facts themselves. Only when philosophy has touched the inert mass of detail, does the harmonious and arranged system spring into view with its power of truly adding to man's knowledge of the universe around and overhead. Only when the search for causation has begun, can our intellectual gains be fully appreciated in our labour of

> Untwisting all the chains that tie
> The hidden soul of harmony.

Such a topic as presents itself to view in the individuality of animals belongs, it may be with all truth affirmed, to the domain of the philosophy which applies knowledge, rather than to the sphere of mere fact and observation itself. This declaration might sufficiently prejudice the subject in the eyes of readers who might be given to view with suspicion any opinion which apparently lowered fact in the scale of credence. But the philosophy we eulogise, bases its existence on the facts we value. It is the mint-stamp of knowledge, which impresses fact with its popular and received value; inasmuch as, without such impress, the fact itself, however valuable, fails to relate itself to its neighbour truths. Hence, if, in the present chapter, we may venture somewhat within the domain of transcendentalism, it may readily be shown that from the sober basis of facts all our philosophy in reality takes origin. By way of at once illustrating this latter proposition, as well as of laying the foundation-stone of our present study, we may enter upon a recital of the facts of individuality as represented in the living series around us.

A superficial acquaintance with the facts of natural history serves to demonstrate the truth of the axiom that every animal originates, directly or indirectly, from that reproductive body we term an "ovum" or "egg." As the result of the development of that egg, the animal body becomes the adult; and of the plant the same truth holds good. The seed or germ undergoing development, and passing through stages which are, as a rule, of well-defined nature, at last appears before us as the perfect plant, which, in its turn, will produce blossom and fruit, and will finally lead us back once more to the seed and germ. One marked and very obvious difference between high animals and low animals is found to exist in the different results to which development leads. The lower animal's growth ceases, and its adult condition is attained, at a stage when the development of the higher being has barely begun. It takes but little trouble on nature's part, so to speak, to convert the matter of life of a low animal or plant into a form like itself. On the other hand, the development of a higher animal means time and trouble, to use a familiar expression, and entails the elaboration and building of a complex body from that which is invariably in its first stages uniform and simple in structure.

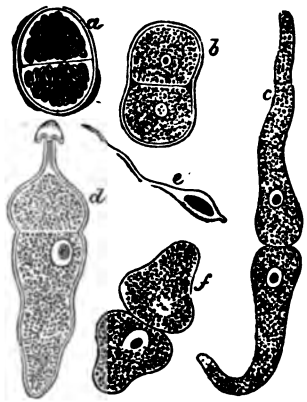


FIG. 183.—GREGARINA AND ITS DEVELOPMENT.

Such an animal form as a *Gregarina* (Fig. 183, *d*), for instance, presents us with a good example of that simplicity of development and that primitiveness of personality which marks the lower fields of animal life. A gregarina is a minute speck of protoplasm found inhabiting the digestive canal of worms, insects, and crustaceans, as an internal parasite. Each gregarina lives what may be described as the simplest form of existence. Existing in the digestive system of its host, it literally lies bathed amidst the nutriment which that host is elaborating for the repair of its own tissues. Possessing no traces of any of the organs belonging to higher animal existence, the gregarina lives by the absorption of the digested fluids of its host; and save for the slow contractions which are sometimes seen to pass in waves along the surface of its body, no movements can be observed whereby its animality might be popularly confirmed. The course of gregarina-development is by no means complex. The body itself, in lieu of an egg or germ, will, sooner or later, become of globular shape (*b*). The little solid body, or "nucleus," seen normally (*d*) in its interior, will vanish by a kind of physiological necromancy, and the body-substance itself will break up and divide into spindle-shaped masses (*a*), for which the thickened rim or margin of the body forms a covering. Then this globular body-margin ruptures; the little spindles of protoplasm escape therefrom; and finally each develops, with but little further change, into a gregarina like that from which it was derived.

Now, such a life-history as this is instructive, especially when viewed from the stand-point of animal individuality. The single gregarina is seen to break up into numerous other gregarinæ, each of which repeats at first the single state, and then the process of division into particles which characterised its parent. Each gregarina, then, may, in natural-history language, be named a "persona," or "person"—that is to say, it is a single or "individual" animal; representing in itself, even as does each of the higher animals, a defined and component element of the animal world. A like remark might be made of many other lower forms of animal life. An *Amœba* (Fig. 184), which differs from a gregarina chiefly in that it possesses an active power of locomotion by pushing out its body substance into long processes (Fig. 184), is likewise a single "individual" animal, which represents, as an oyster or a bird does, a well-defined unit quantity in the sum total of the living series.

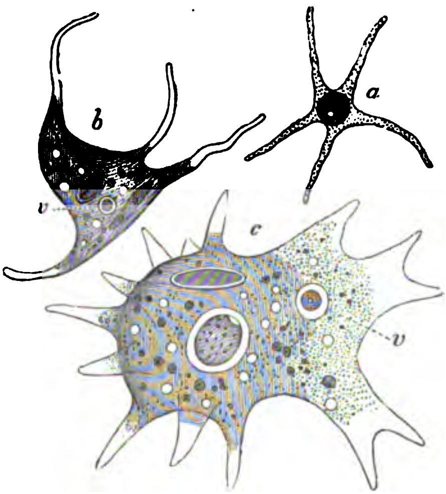


FIG. 184.—DIFFERENT FORMS OF AMŒBÆ.

There is, however, one important epoch in the life of both gregarina and amœba, when each organism—for both exhibit essentially the same course of development—shows a tendency to lose its individuality in the division of its body to form other individuals. At one stage in its development, namely, when filled with the miniature "spindles" or protoplasmic particles (Fig. 183, *a*) into which it has divided itself, the gregarina or amœba in reality becomes a colony or aggregation of beings. But such a tendency is at the most transitory, and the temporary colony speedily resolves itself into a diffused and separated mass of young organisms, whose individuality, and indeed whose whole existence, is due to the destruction of those of their parent. In another sense, the amœba may occasionally show this tendency to lose its single and defined individuality in that of the compound colony. For occasionally particles or offshoots of the amœba's protoplasmic body detach themselves therefrom, and pass away like precocious emigrants from the parent-frame to assume all the functions of amœbæ on their own account. In this way, and through the exercise of the simplest reproductive process we know of—namely, that of "fission," or simple division of an animal's body into two or more new beings—the amœba-body converts itself from a single "individual" into a mother-colony, with offshoots and emigrants seeking a life and existence of their own. And, last of all, in the gregarina itself, we may find certain important variations in structure which seem to threaten the destruction of the individualism of its body, and to merge the individual in the crowd. For we know not merely of gregarinæ which consist apparently of but one mass of protoplasm, as already described, but of others which exhibit a division of body into two (Fig. 183, *d*) or even three compartments. What the significance of this tendency to division or segregation may be, is yet matter of conjecture; but at first sight its meaning would seem to foreshadow the same destruction of individual constitution which, in their development, these organisms unquestionably exhibit.

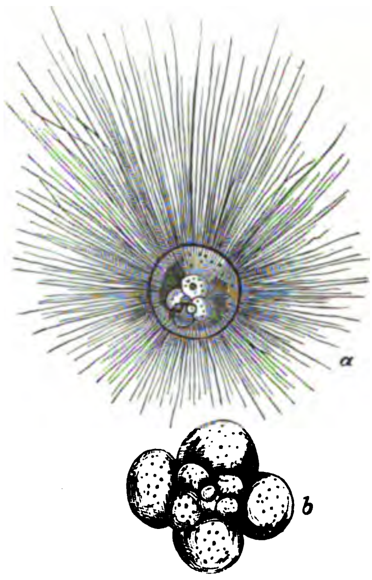


FIG. 185.—FORAMINIFERA.

Even in the lowest animals, each consisting of a minute mass of protoplasm, there is thus observed a tendency, at some period or other of their life-history, to depart from the single state, and by division, or, as it is named, "segregation," of their substance, to form a "colonial" or compound organisation. But even in the lower confines of animal life, which harbour the amœbæ and gregarinæ as typical tenants, are represented states and phases of organisation which are purely and typically "colonial." Thus, that low form of life known as *Myxodictyum* normally exists as a collection of protoplasmic particles, such as would be exactly imitated if a number of amœbæ banded and fused themselves together. It is equally interesting to note that the vast majority of the *Foraminifera* (Fig. 185), or "chalk-animalcules," are to be regarded as exhibiting a compound constitution. For, in these animalcules, which are as a rule of compound nature (Fig. 185, *b*), the growth of new divisions of the shell takes place by a process of budding, and through the production of new protoplasmic units which remain organically connected with the original mass. Nor are the lowest plants to be left out of consideration in this recital of primitive colony-making. The cryptogamic botanist well knows certain green specks of microscopic size, each called *Chlamydomonas*, which swim freely in fresh waters, by means of two long cilia, or miniature eye-lashes, projecting from one extremity of the body. Now, there exist in stagnant waters certain other curious bodies, long known as "Globe-animalcules," before they were ascertained to be lower plants. Each of these bodies is scientifically named a *Volvox* (Fig. 186, *d*), and appears to consist of a hollow globe or sphere, covered with innumerable little specks of bright green, and

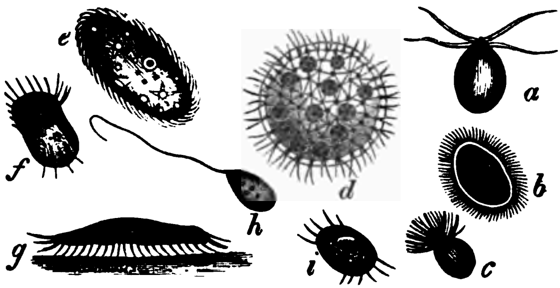


FIG. 186.—VOLVOX (*d*) AND VARIOUS ANIMALCULES.

swimming freely through the water by the waving action of the fine cilia which fringe its body. More minutely examined, this rolling globe is found to consist of a collection of little green bodies, each of which, in all essential details, exactly resembles a single Chlamydomonas. The filaments fringing the volvox are in reality pairs of cilia like those of Chlamydomonas, and are attached to the little green bodies aforesaid. Thus volvox, so far from being an animal, is, firstly, a rootless lower plant; and, secondly, so far from being one plant, volvox is in reality a colony of the lowest members of the vegetable world. There are many other *Algæ* (or lowest plants) which resemble volvox in their compound nature; and thus the beginnings of plant-life appear to present us with a tendency towards colonisation, similar to that which faces us on the threshold of the other series of living beings.

In the curious group of the sponges (Fig. 187), we may find our next convenient halting-place in our researches into animal individuality and its variations. From forming the *bête noire* of the naturalist of former years, who was troubled in his mind as to the animal or plant nature of the sponges, to occupying a singular and anomalous position in the animal classifications of to-day, this group of organisms has attained a well-merited celebrity. The living parts of a sponge—that is to say, the parts which form and make the sponge-framework, and which alone concern us in our present investigation—consist of masses of protoplasm, which are in their way strictly comparable to the minute bodies, or "cells," of which our own tissues are built up. A sponge, as to its living parts, is a mass of protoplasmic cells, "some of which," as Huxley puts it, "have all

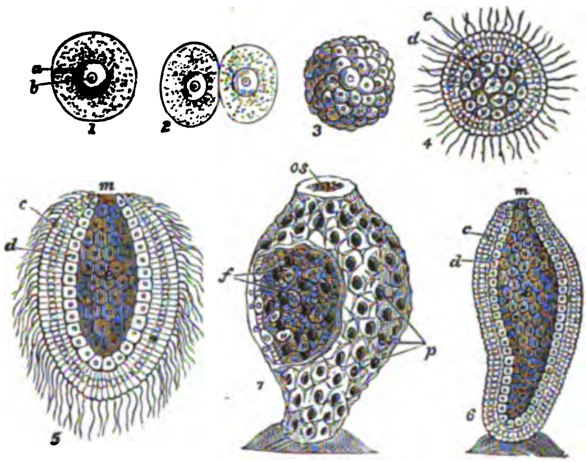


FIG. 187.—SPONGE AND ITS DEVELOPMENT.

the characters of *Amœbæ*; while others are no less similar to monads"—these latter being microscopic masses of protoplasm, furnished, like chlamydomonas, with two waving cilia. The comparison of a sponge to a kind of "submarine Venice," with its canals, along the banks of which the inhabitants (or masses of protoplasm) reside, and through which flow the water-currents bringing particles of nourishment to these denizens, is therefore seen to be fully justifiable in one sense. Still more justifiable and appropriate would such a metaphor be, could we prove that the sponge was in reality what the simile indicates, namely, a colony of animals—seeing that the comparison of the sponge to the Adriatic capital, derives its whole force from the assumption that its personality, like that of the city, is compound, and is not simple and single, like that of the element or unit. As we shall hereafter see more plainly, the sponge must be judged, like every other living being, not by its appearance or by what it simulates, but by what it originated from. As an apparent collection of organisms, it might well be regarded as a veritable colony. On other grounds, the sponge might appear as rightfully entitled to be considered as single and undivided an animal unit as a man. The grounds on which these opinions are based need not now be specified, but the history of how a sponge grows, finds its appropriate place at this stage of our inquiry. The most typical sponges, as already shown, grow each from an egg (Fig. 187, 1), which passes through characteristic stages of development (2, 3, 4), and finally becomes a cup-shaped body (5), possessing a double wall (*c*, *d*), the cavity of the cup opening outwardly by a distinct mouth (*m*). Then pores or openings (7, *p*) are formed in the wall of this cup, placing

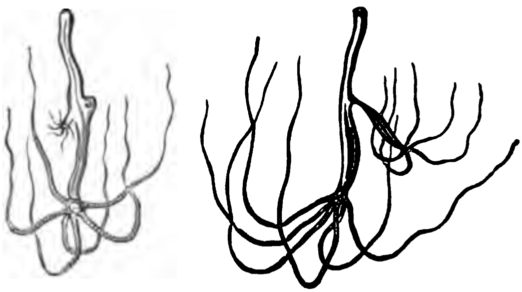


FIG. 188.—HYDRÆ.
(Young hydræ are represented budding from the parent in each figure.)

its interior in a new fashion in communication with the outside world. The outer wall of the cup, and the inner wall likewise, consist of cells; and those of the inner wall finally come to possess cilia, which, by their constant motion, cause currents of water to flow into the inside of the cup through the pores, and outwards by its mouth.

The nourishment of a sponge is subserved by these water currents, bringing food and oxygen to its living cells; and the simple or cup-shaped sponges (Fig. 187, 7), of which many species are known, exhibit a history resembling that of which the outlines have just been sketched. The horny sponges, the skeletons of certain species of which we use in our domiciles, may and do develop into organisms of a more complex character than the cup-sponges present, and they may also originate from buds as well as from eggs. The common green fresh-water *Spongilla*, found growing on the sides of canal locks and in similar situations, illustrates the former method of development. This species propagates its kind by veritable buds, whilst it also produces eggs; and another curious fact, possessing a significant bearing on the individuality of the sponges, consists in the observation that when two Spongillæ are placed in contact they merge together into one. They may also be divided artificially, or may separate spontaneously into two or more organisms, each of which will lead an independent existence. The sponges, then, may be hereafter referred to as a group of animals which, whilst originating from eggs, as do higher beings, yet retain much

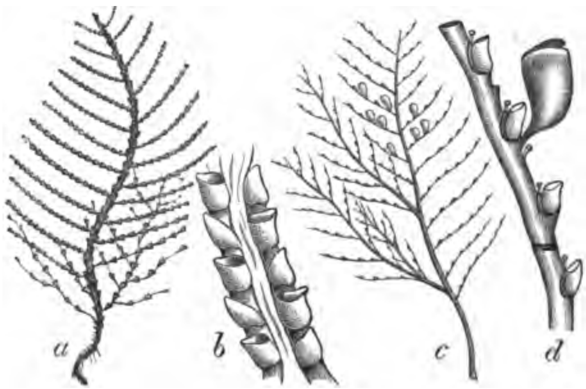


FIG. 189.—ZOOPHYTES. *b* and *d*, magnified portions of *a* and *c* respectively.

of that tendency to segregation and separation into distinct and elementary parts which we may reasonably maintain is probably a primitive and fundamental character of all living beings.

Nearly allied to the sponges are the little freshwater polypes named *Hydræ* (Fig. 188), and the marine plant-like organisms familiarly known as "Zoophytes" (Fig. 189). Here we at once enter the domain of animal "colonies," and find intensified and illustrated in the plainest fashion those tendencies towards division and segregation of body which, at the best, are but dimly marked in lower organisms. The hydra, existing as a little green tubular body—attached by one extremity to a water weed, and exhibiting at the free end a mouth and tentacles—at certain seasons exhibits a growth of small projections on its sides. As these projections increase in size, they grow into the likeness of young hydræ (Fig. 188), each developing a mouth and tentacles, and possessing, so long as they adhere to the parent body, free communication with the interior of the latter. These budded hydræ may in their turn produce buds, and a veritable genealogical tree may thus be viewed, in that three generations of polypes remain connected as they were produced by the parent stem. The hydra thus converts itself normally into a compound colony through this process of budding. But this state of matters is, at the most, transitory and temporary in hydra-existence. The budded individuals, sooner or later, break contact with the parent-body, and pass to seek a new lodgment and to begin life on their own account; leaving the parent, single as before, but connected, as we shall presently note, to the free offspring by ties which our transcendental philosophy makes clear and plain. It may lastly be remarked that, in respect of structural constitution, the closest similarity exists between a cup-sponge and a hydra. Both possess tubular bodies, and both consist of two cellular layers. Modern zoology has emphasised this likeness by placing the sponges in the same great group (*Cœlenterata*) which contains the hydra and zoophytes. It is conceivable enough, indeed, that a hydra is simply a specialised sponge-form possessing its compound and colonial nature somewhat disguised beneath an apparently single personality.

The constitution of a "zoophyte" (Fig. 189) is mere matter of repetition after the recital of the hydra's peculiarities. The plant-like Sertularian or "sea-fir" (Fig. 189, *a*), which we dredge by the hundred, growing on oyster-shells; or the Flustra (Fig. 190) or "sea-mat"—of higher organisation than the "sea-firs," but presenting likewise the aspect of a marine plant—present us each with a veritable colony of more or less similar beings, united in the bonds of close relationship. Thus the sea-fir, as the type of the true zoophyte, bears on its branches hundreds of little cups (Fig. 189, *b*, *d*), each of which contains an animal strictly corresponding in structure to a hydra (Fig. 188). This multitude of animal bodies is bound together in intimate union. The stem and branches are hollow, and each little mouth and body, digesting the food its tentacles have captured, transmits that food to swell the general stream of nutriment circulating through the tree-like fabric. Thus we find the principle of co-operation herein illustrated in plainest guise. Each little animal derives its own share of nutriment from the general store it has helped to manufacture; and the exercise of the principle in question is all the more perfect, in that its practice is free from those petty jealousies and personal inducements to infringe the duty of equal and harmonious work which usually beset the co-operative societies of higher existence. The remaining points which call for notice in the history of the zoophyte may be shortly summed up. The little members of the colony are continually dying off as the result of their life-work, but their place is supplied and the colonial loss repaired by the production of new buds. As leaves fall from a tree and are replaced by the growth of new buds, so the zoophyte-units wither, fall, and in like fashion are represented anew in the constitution of the organism. Then, lastly, the origin of the zoophyte in an egg is worthy of note. Each zoophyte originally springs from an egg, which, passing through the changes common to the early development of all ova, produces an embryo which settles down and attaches itself to some fixed object.

This first embryo next assumes the likeness of a single little hydra-like unit of the zoophyte colony. Then the process of budding commences. Bud after bud is produced, each growing into the likeness of the primary one, and all adhering together as parts of a connected organism, until we find reproduced before our eyes the tree-like form with which our research began. Thus a hydra and a zoophyte are very nearly allied ; the chief difference between these organisms consisting in the fact that, whilst the buds remain permanently connected together in the latter, they are intended to seek an independent existence in the former. True, there are buds produced by the zoophyte which in many cases detach themselves and swim freely in the sea under the guise of "jelly-fishes," and which, apart from the zoophyte, mature the eggs from which new generations of these plant-like animals will spring. But these floating jelly-fishes, despite their freedom, are in reality buds of the zoophyte. They are connected by all the ties of blood-relationship with their plant-like parent, and are essential parts of the zoophyte-colony even when separated from the parent-organisms by many leagues of sea.

In all zoophytes the component units of the colony belong to one type. Whatever their function, they are modelled on the type of the hydra, and on that of the ordinary nutritive members of these animal trees. Even the jelly-fish buds just mentioned, are but modifications of the hydra type. This interesting and important feature in their history is proved by the fact that, when their generative functions have been discharged, they may revert to the form of the nutritive members of the colony. We know, lastly, of cases in which a zoophyte-colony may number no fewer than seven apparently different kinds of members; these units, notwithstanding the diverse functions they perform, exhibiting a fundamental agreement in type and structure. There is seen, therefore, a close parallelism between the repetition and modification of parts in the colonial zoophytes, and the vegetative repetition of the leaves and buds of the tree.

The Flustras, or "Sea-mats" (Fig. 190), illustrate a slightly different phase of colonial relationship in animals from that presented by the zoophytes. We have seen that each member of the zoophyte-colony exists in intimate structural relationship and connection with every other unit of the compound organism. But in the "Sea-mats"—each of which presents us with the appearance of a piece of pale brown seaweed, bearing on either side its hundreds of little cells (Fig. 190, *b*), each containing a little tenant—the individual animals of the colony do not communicate with each other. On the contrary, each member of the sea-mat colony is perfectly distinct from all its neighbours, and lives enclosed in its separate domicile. But for the union of its cell-wall with the walls of other cells, each little sea-mat unit is a thoroughly independent being; and even the so-called "colonial nervous system," which was long believed to connect the members of the fraternity in a common bond of sensitiveness, has been proved to be non-existent. It is highly interesting, therefore, to find that compound animals may, like the zoophytes, possess their individual or component units in close structural harmony and relationship; or

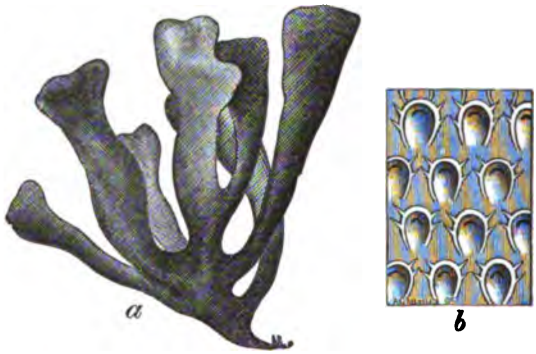


FIG. 190.—FLUSTRA, OR SEA-MAT.
a, natural size; *b*, magnified, showing the cells.

may, on the other hand, like the sea-mats, exhibit a collection of animals each of which is thoroughly independent of its neighbours. That such differences have not originated in any haphazard fashion, but that they are a veritable result of the tendencies of development, is readily enough proved. For, whilst each member of the zoophyte-stock is in free and full nutritive co-operation with its neighbours, each "sea-mat" unit preserves within its own cell, not merely a perfect digestive apparatus, but a nervous system, and reproductive or egg-producing organs as well. The independence of the "sea-mat's" members has been accompanied by the development of a much higher organisation than is found in the interdependent zoophyte-units; although, of course, such a statement of fact still leaves the origin and cause of the independence of the higher "sea-mat" units an open question. But in its manner of growth, the latter colony resembles the zoophyte. Each unit has the power of adding to the colony by the process of budding already described; whilst each member of the colony possesses, likewise, the power of giving origin to eggs. Each egg, undergoing its full development, produces first one primitive unit, and thereafter and from this unit develops, by budding, a whole colony, with its hundreds of component and similar beings.

There exist in the ranks of that curious class of beings, the internal parasites, certain interesting examples of the compound animal form. A tapeworm (Fig. 191), for instance, inhabiting the digestive tract of some warm-blooded quadrupeds, and attaining a length, it may be, of many yards, consists of a very minute head (Fig. 191, 1), a slender neck, and many hundreds of so-called "joints." At first sight, these "joints" might be regarded as resembling in their nature those of the ordinary worms, and as therefore possessing no distinct individuality on their own account, or separate from that of the organism of which they form part. But the examination of the joint of a tapeworm (Fig. 191, 2) shows us that in reality it preserves a separate and apparent individuality of its own. In other words, it is not merely a part of one animal in the sense that the joint of a backbone is part of a fish or bird. It corresponds, on the contrary, with a member of the zoophyte or "sea-mat" colony in that it represents a highly specialised and individualised unit of an organism, that organism being of compound nature. Each "joint" of the tapeworm contains a complete set of egg-producing organs (*o*), and presents other indications of its semi-independent character and constitution. Connected to its neighbouring joints by water-vessels as well as by the nerve-cords, the joint is in intimate union with the other units of the colony. But it is, nevertheless, a distinct unit after all; and the tapeworm is not a single animal, but, like the sea-mat and zoophyte, a "colonial organism."

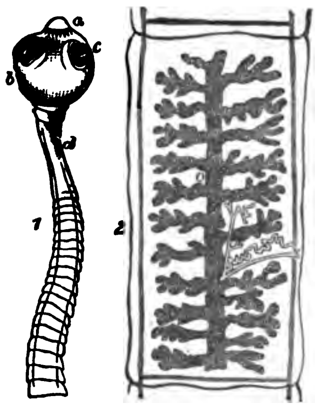


FIG. 191.—TAPEWORM.
1. Head, suckers, neck, and joints; 2. A single joint (magnified).

Amongst other and true "worms," however, we find curious instances of development, which, in our consideration of the origin of the conditions we are studying, may serve to elicit some valuable hints concerning the causation of colonies at large. The little river-worms known as the Naïdides (Fig. 192), occasionally exemplify certain peculiar modes of reproduction which deserve careful study. A naïs may be seen to exhibit a slight constriction towards the posterior part of its body. As this constriction deepens, a new head, eyes, and tentacles are seen to be formed at the spot in question (Fig. 192), and a second naïs is thus viewed budding from the hinder extremity of the original individual. This new being, produced thus by the division of the parent body, sooner or later becomes detached therefrom, and seeks an independent existence. Cases have been observed in which as many as six new individuals have been produced from a single naïs. In *Cirrhatula*, another worm-genus, Müller relates that he found three new individuals adherent "in one length." "The mother," he remarks, "had thirty pedate segments; the youngest daughter, or that nearest the mother, had eleven, but the head was not yet developed. The most remote had seventeen rings, with both head and eyes, and, moreover, the tail of the mother; the middle one had seventeen segments and a head." It is matter for remark that no egg-producing organs exist in the new individuals thus budded, which may therefore be named "neuters," like the "workers" among the bees. The last-formed individual, however, in the naïs, develops reproductive organs, and thus the continuance of the species in time is duly provided for.

FIG. 192. NAÏS, OR FRESH-WATER WORM.

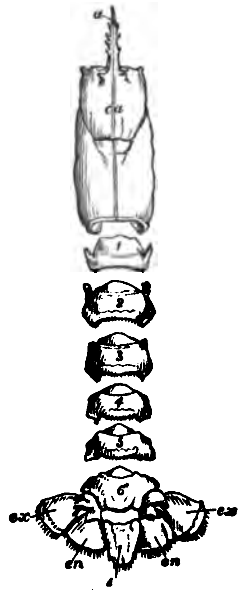


FIG. 193.—JOINTS OF LOBSTER.

In connection with the production of like parts by budding—a process known as that of "vegetative repetition" of parts, and producing what is known as the "serial homology" of animals—it is interesting to note that the twenty joints or so of which an anima like the lobster (Fig. 193) is composed, are constructed, irrespective of size or function, upon one and the same type. The same remark holds good of an insect, of a centipede, of a spider, or other articulated animal. Very striking is it to find that a lobster's "feelers" really correspond in nature with its legs; that its eye-stalks agree with part of the appendages of its tail-joints, and that its jaws are simply the feet of the head, so to speak, modified for chewing. These varied organs arise from a common type, just as the joints which bear them exhibit a singular uniformity of structure. Hence a lobster, or other Articulate animal, gains the best possible title to be named colonial, in that it is not merely composed of visible "units," but also in that these units are modifications of a common and single plan. In connection with the curious phases of worm-growth observed in the Naïdides (Fig. 192), we may note that the individuals of the centipede-class increase in size and add new segments to their bodies in a somewhat

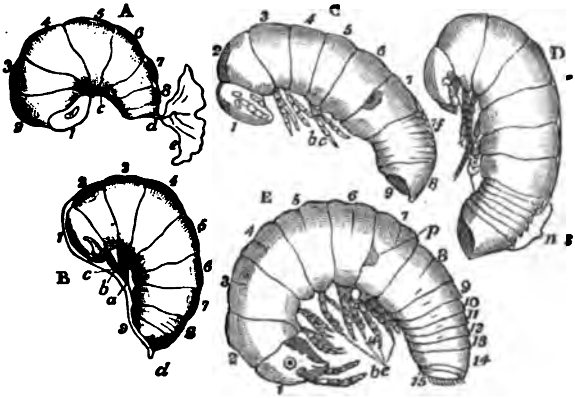


FIG. 194.—DEVELOPMENT OF JULUS.

similar fashion. When a young centipede or gally-worm (*Julus*) (Fig. 194) is attaining its full growth, new joints are seen to bud out between the last segment but one (C, *f*; D, *n s*) and the joints in front thereof; so that the last-formed joints (E, 9–14) in a young centipede are placed towards its tail-extremity. If we could imagine that some of these last-formed segments developed a head, and separated themselves from the parent-frame as a new being, we should possess an exact imitation of the process whereby the young Naïs (Fig. 192) originates from its parent-form.

An interesting biological speculation has arisen in connection with the personality of those familiar animals the Starfishes (Fig. 195). Here we find a central body or disc (Fig. 195, 1), with, in the common species, five rays or arms, containing each an exactly similar arrangement of the organs of the body, diverging therefrom. Haeckel's ingenious speculation that "each arm of the starfish essentially corresponds in its organisation with an articulated worm," is objected to by some naturalists, and amongst others by Huxley, who agrees that the starfish, or echinus, may have arisen from a worm-stock, but argues that both the starfish and sea-urchins owe to secondary modification their characteristic form. Haeckel, however, is supported by authority so eminent as Gegenbaur, who remarks, that "there is a certain amount of independent organisation in each arm of a starfish; its organs . . . have exactly the same position as the homologous organs of an Annulate worm. If, then, we compare each of the budding arms with a worm-like organism, we must regard the starfish developed by this process of gemmation as corresponding to a multiple of such organisms; and, further, we must recognise in this phenomenon the same process of gemmation (or budding) as that which takes place in other lower animals; for example, in the compound ascidians (or sea-squirts) It is a process," says Gegenbaur, "in which several separate animals are simultaneously budded off; the process does not go on till these animals are completely separated, but stops in such a way as to keep them connected together as an individual of a higher order." We know, as just remarked, of allied cases amongst the sea-squirts, where several beings are budded in star-shaped fashion (*Botryllus*) to form a colony. And when we reflect that, as every sea-beach shows, a starfish may be deprived of all its arms, and as one arm (Fig. 195, 3) may not merely live an independent existence, but will in time reproduce the other four, Haeckel's idea that a star-fish is really a collection of worm-like beings, is seen to be so far supported by comparative anatomy and by the analogies of development as well.

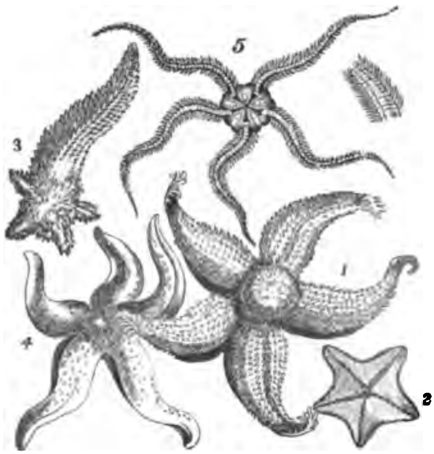


FIG. 195.—STARFISHES.

The list of animal classes in which a colonial constitution is developed may appropriately enough be concluded with the brief recital of the process whereby the *Aphides*, or plant-lice (Fig. 196), which devastate our plants, and the bees themselves, propagate their race—the latter forming social colonies which in their essential nature may be deemed analogous to the zoophyte-stocks of lower life. The single and undivided personality of a bee or an aphis would at first sight seem to admit of no question. Each presents itself to view as an active being, possessing no structural connections with neighbour-organisms, and evincing all the apparent marks and characters of an ordinary "individual." But our philosophy relies, as already remarked, more on the determination of what an organism has arisen from, than upon what its apparent constitution may be. Hence the consideration of a bee's origin contains the answer to the question of its true nature. In the reproduction of the bee race, certain of the eggs are impregnated or fertilised, whilst others are allowed to develop without the performance of this process—rightly deemed of essential nature to the propagation of both animals and plants. Now, those eggs of a queen-bee which she lays in an *unfertilised* condition, invariably develope into *drones*, or male bees, whilst the fertilised eggs become females, or queens, or neuters—the latter being merely imperfect females, on whom devolves the whole work of the hive. In the plant-lice, the eggs normally produced by both sexes in the autumn lie dormant all the winter, and then give rise to wingless female aphides alone. These latter produce, in viviparous fashion, a winged or wingless progeny, which in turn repeat the fertility of their parents. As Huxley remarks: "The number of successive viviparous broods thus produced has no certain limit, but, so far as our present knowledge goes, is controlled only by temperature and the supply of food. *Aphides* kept in a warm room, and well supplied with nourishment, have continued to propagate viviparously for four years."

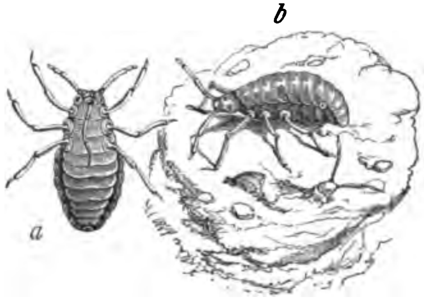


FIG. 196.—PLANT-LICE.
a, wingless insect; *b*, wingless insect.

Now, close research has disclosed other cases of this apparent violation of the ordinary rules of reproduction in the animal world. We know that in certain saw-flies, some of the female insects will, of themselves, lay unfertilised eggs, which develop into male saw-flies. In some insects (*Chermes; Coccus*) no males have been discovered. There are also certain caterpillar-like females among the butterflies and moths (e.g. *Psyche* and *Solenobia*) which lay unfertilised eggs giving origin to female insects like themselves, whilst from fertilised eggs the two sexes are developed in nearly equal numbers. It may be conceded that in the case of the bees, as insects of specialised type, we are dealing with insects in which true unfertilised eggs develop simply into drone or neuter-insects. But in the lower plant-lice, the process is more nearly related to the budding of the zoophyte. Each aphis, produced viviparously from the parent-body, grows from

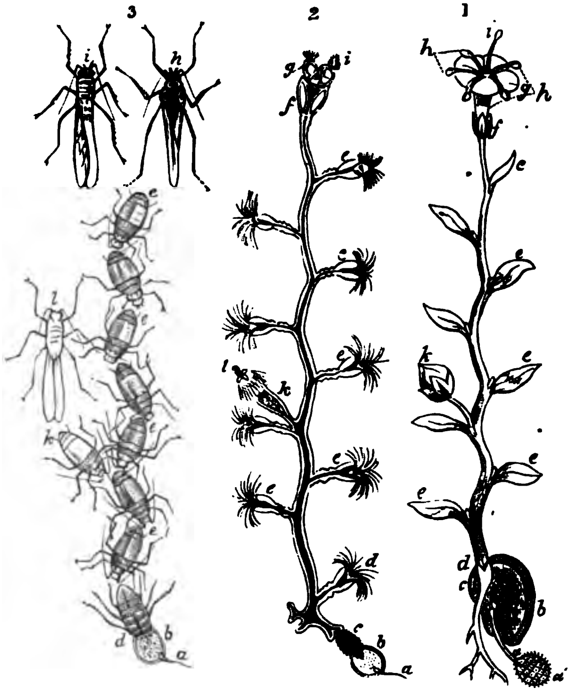


FIG. 197.—COMPARISON OF DEVELOPMENT in (1) a Flowering Plant; (2) a Zoophyte; and (3) a Colony of Plant-Lice (*Aphides*).

a structure which, whilst it resembles a true egg, does not pass through the development of that body, and is therefore called a *pseud-ovum*. Gradually this "pseud-ovum" grows into the likeness of the aphis, which, after birth, will develop within itself like bodies, and thus carry on the work of continuing the species in time. If we suppose that the aphides remained connected together (Fig. 197, 3), instead of preserving a distinct structural identity, we should reproduce in this insect-tribe an exact *facsimile* of the zoophyte-colony (Fig. 197, 2), with its budded branches (*e*) and its ever-increasing wealth of members. For plant-lice reproduction is in reality a process of budding, and the colonial constitution of the insects is really veiled and masked by their freedom from the parent-stock. They may, in truth, be compared to those free-swimming "jelly-fish" buds which the zoophyte develops upon and liberates from its branches, but which remain, nevertheless, in the gaze of philosophy, essential parts and constituent units of the animal-tree which gave them birth. Lastly, let us bear in mind that the egg itself is merely a *reproductive bud*; and that there are gradations thus to be witnessed leading from the true egg, with its normal development, after fertilisation, to the pseud-ovum with its bud-like career, and finally to the bud itself, which, as we shall see, never attains, let its development be what it may, to the rank of a true individual animal. A glance at Fig. 197 will serve to show the correspondence between the development of aphides (3), zoophyte (2), and plant (1). In each case, the bulk of the compound organism is provided for by a process of "budding;" whilst, as the colony reaches its higher development, the production of new and independent individuals, through eggs and seeds (*h*, *i*) respectively, is witnessed.

Rassemblons des faits pour nous donner des idées—taking the term "ideas" as synonymous with that philosophy the praises of which have already been sufficiently extolled. From the array of facts through which we have progressed, what ideas or inferences concerning the origin of animal colonies can be reasonably derived? And, firstly, let us inquire what definition biology is prepared to offer as the criterion of animal or plant individuality. It is perfectly clear that some such test of an animal's nature is demanded, for instance, by the very diversity of form and constitution which the animal kingdom presents. An "individual" animal we may readily define, in respect of its structural constitution, as one in which all its parts and organs exist in such intimate relationship, that interference with one organ or series means the disorganisation of all. Close and intimately connected structure, forms in reality the plainest criterion of the "individual" animal viewed from that side of biology which regards morphology or "structure" as the basis of its philosophy. The integral constitution of its material parts is thus the plain test of an animal's "individuality," from the structural point of view. On such grounds, the man or the dog is obviously a much more typical "individual" than a "newt," which can part with its tail or legs, and yet live and develop new members in the place of the injured parts; and the newt, in turn, is a truer "individual," judged by its structural interdependence, than the zoophyte, whose buds as they fall are replaced without material disorganisation of its constitution. Professor Asa Gray well sums up the structural view of the "individual," when he remarks: "The idea of individuality which we recognise throughout the animal and vegetable kingdoms, is derived from ourselves, conscious individuals, and from our corporeal structure and that of the higher brute animals. This structure is a whole from which no part can be abstracted without mutilation. Each individual is an independent organism of which the component parts are reciprocally means and ends."

But another method of viewing the personality of the animal is found in the deductions of physiology. Not "what it is," but "from what it has originated," is the test of physiological individuality. That alone, in physiological eyes, is an "individual" animal which is the total result of the full development of a single egg. Whatever a single egg becomes, in other words, represents the individual animal or plant. Testing some of the examples already noted by this criterion, we may readily enough distinguish the true individuality of the animal races we have passed in review. With respect to the personality of the higher animals, this test is susceptible of the plainest illustration. Each quadruped, bird, reptile, fish, oyster, &c. springs from a single egg. When each of the bodies in question has been formed, we know that the full development of the egg or germ has been attained. Hence each of the aforesaid animals is an "individual" pure and simple, when judged by the standard of its representing the total result of a single germ-development. With the other illustrations, the case should be equally clear. A zoophyte (Fig. 197, 2) and a sea-mat (Fig. 190) spring each from a single egg, and the process of budding gives to each the plant-like form and the colonial organisation familiar to us in these beings. Hence the whole zoophyte, and the sea-mat *in toto*, are "individuals." What then, it may be asked, are the separate members of either colony? Not "individuals"—for they merely represent *parts* of a single egg's development—but "zooids" is the biological reply; comparable, it may be, to separate "organs" and "parts" in the higher animal, but not constituting of themselves "individual" personalities. The cases of the gregarina (Fig. 183) and sponge (Fig. 187) are each resolvable without difficulty on the premisses just indicated. The single gregarina, arising from a true process of development, is a single individual, but the divided gregarina represents a compound personality. The whole sponge, arising as it does from an egg, is an "individual;" and if each of its protoplasmic units be held to be not merely a cell, but a semi-independent and amœba-like organism, the sponge is a "compound individual" in addition. So also with a tape-worm (Fig. 191) or other allied organism. The whole "worm" is one compound "personality," or one "individual," because it has arisen from a single egg, and because it represents the full development of that body. So likewise with the hydra (Fig. 188). Arising from a single egg, it gives origin by budding to other hydræ which break away from the parent-organism, and live an independent existence. But as these buds, although independent of the parent-body, nevertheless represent part of the development of the single egg, we see that the "hydra-individual" is not the parent-hydra alone, but that parent, *plus* all the buds or hydræ which are produced by it. The next "*individual*" existence begins with the production of an egg. Till that event happens, all the hydræ, produced by budding or otherwise, are merely *parts* of an individual, and have of themselves no distinct personality. With the zoophyte and the hydra, therefore, the case for the "individual existence," as represented by the compound animal (*i.e.* by the single animal *plus* its buds) seems clear. Quoting Professor Huxley once more, we may say that "the multiplication of mouths and stomachs" in a zoophyte (Fig. 197, 2)—as the result of the budding of new members of the colony—"no more makes it an aggregation of different individuals than the multiplication of segments and legs in a centipede converts that arthropod into a compound animal." "The zoophyte," continues the voice of authority, "is a differentiation of a whole into many parts, and the use of any terminology which implies that it results from the coalescence of many parts into a whole is to be deprecated." The plant-lice (Fig. 197, 3) are to be viewed in precisely the same light. For, as Professor Huxley remarks, "no doubt it sounds paradoxical to speak of a million of *aphides*, for example, as parts of one morphological individual; but beyond the momentary shock of the paradox, no harm is done. On the other hand, if the asexual (*i.e.* the products of the pseudova) *aphides* (Fig. 197, 3, *ee*) are held to be individuals, it follows as a logical consequence, not only that all the polypes on a cordylophora (or zoophyte) are 'feeding individuals,' . . . . . . while the stem must be a 'stump individual,' but that the eyes and legs of a lobster are 'ocular' and 'locomotive individuals.' And this conception is not only somewhat more paradoxical than the other, but suggests a conception of the origin of the complexity of animal structure which is wholly inconsistent with fact."

The point to which our inquiries have led us may be summed up in the conclusions, firstly, that animals exist either as simple or as compound "individuals"—the former typified by the higher animals at large, and the latter by the zoophyte and the tapeworm tribe. A second inference deducible from our study, is that the personality of an animal is in reality the direct result of its development, and of the manner in which its parts and organs are structurally related to each other. And a third deduction follows from our biological experience, namely, that the separate parts—or "zooids," as we term them—of a compound individual, are not necessarily connected by structural ties to the parent or primitive form. On the contrary, like the detached buds of hydra, the free jelly-fishes of the zoophytes, or the apparently free and independent members of the plant-lice fraternity, the "zooids," which make up the personality of the true "individual," may be scattered far and wide from the parent organism, and be yet tied by firm transcendental bonds to the stock of which they are really intimate parts.

But a further question still besets us, namely, as to the origin and meaning of the variations which animal individuality thus presents to view. If the true function of philosophy be that of affording a clue to the meaning of this world's phenomena by placing facts in their due relationship to each other, it follows that the higher knowledge of the varying "individuality" of living beings must resolve itself into an explanation of the causes through which such personality has been acquired. Such philosophy is necessarily founded upon that view of the order of nature which regards the universe as an arena of constant modification and progressive change, as opposed to the theory of its originally and inherent stable constitution. It is the theory of evolution, as opposed to that of specially designed ways and means in nature, which presents itself as the exponent of animal "individuality" and its causes. On the former hypothesis alone, is the question of the individuality of living beings debatable; since the idea of stability in living organisms presents a dead wall to the further discussion of the present as well as most other biological topics. Hence the data of evolution and progressive descent, with modification, must, in the present instance, be used as the pathway along which our explanatory steps are to be pursued.

That every living being begins life in a simpler guise than that in which it spends its adult existence, is a kind of home truth in every-day life, as it is a dictum of biological science. The practical difference between a low and a high animal lies in the fact that the former does not advance much or anything beyond its primitive condition, whilst the latter in time exhibits an infinite complexity on its early structure. A gregarina or an amœba are lower than an oyster, because development leaves the two former with bodies but little more complex at the end of life than at their birth. The oyster, on the contrary, beginning as an amœba-like germ, takes farewell of development as an organism of high complexity, and as one whose frame exhibits a marked differentiation of its organs, parts, and tissues. Now, if the body of a higher animal be analysed out into its constituent parts, we may, microscopically, speak of it, with the greatest possible exactness, as a collection of cells and fibres—or more simply as a collection of cells, for the fibres arise from and are developed out of cells. So that even the complex frame of humanity, is truly resolvable into groups of cells which, however varied in structure they may be, arise in their turn, at the commencement of development, first, from exactly similar cells, and more primitively from one and a single cell—the ovum or egg itself. Thus true is it that "all the higher forms of life are aggregates of such morphological units or cells, variously modified."

But development teaches us something more. Every animal above the rank of the amœba and its kind—and even these latter may be included in the statement—passes, in the course of its personal progress towards maturity, through a stage in which the original substance of the single primitive cell or egg breaks up into numerous other cells, through the subsequent arrangement of which, the body of the organism is in due course developed. This epoch, our developmental studies have familiarised us with under the designations of "segmentation" and the "morula-stage." In other words, there is an early tendency on the part of every animal and plant to depart from the single-celled stage, and to exhibit a compound or collective structure. The egg, at first one cell, thus divides to form a colony. Nor may the transcendental glance cease at this stage of matters. If a colonial aggregation of cells at a very early stage of development be a reality of life,—if some animals, sponge and hydra for example, are but collections of primitive cells,—a no less stable fact is expressed in the statement that in the adult body of the highest animals such colonial aggregations are still to be traced. Each tissue of the human frame, in its most vital phase, is a colony of cells—a compound cellular "individual," numbering its units by the thousands, and possessing the power of growing, and reproducing new cells, as truly as the zoophyte, by budding, repairs the constant loss to which its component parts are subject. And there may further exist in the highest animals, cells or units which exhibit well-nigh as complete an independence of the frame in which they occur as do the animalcular hosts outside. Thus the white corpuscles of the blood (Fig. 198) of all animals exactly resemble amœbæ in

FIG. 198.—WHITE CORPUSCLES OF THE BLOOD.
Different forms assumed successively by a white blood-corpuscle.

structure, size, and movements. They are known to pass through the walls of blood-vessels, to roam through the body at will, and are seen to exhibit an utter and complete independence of all the tissues of the body. More curious still, these white corpuscles have been seen to ingest solid particles, exactly as an amœba or allied form receives its particles of food. It is not more wonderful, if we think the matter over, to find in our own bodies many true "colonial" aggregates of cells, than to discover that certain of the cells thereof have developed an independence and freedom of motion equal to that of an animalcule living in its native haunts, and carried out through movements of exactly similar nature to those performed by the amœba itself. Thus a first halting-place in our philosophy of individuality may readily be found in the declaration that the "colonial" or "compound" body is in reality the normal constitution of all animals, save the very lowest. With the advance of life there has been exhibited a progress in complexity, and this progress has found structural expression in the conversion and multiplication of the original unit of the germ into the colonial and compound state. We ourselves are "compound" individuals, in the sense that our physical personality is not single in any sense, but markedly multiple. Our individuality may be named doubly "compound," in the sense that, whilst each tissue may be held to represent a "zooid," or colonial member of the body as a whole, the tissues are, in their turn, made up of "cells," each of which is a distinct morphological unit.

If the above deduction be correct, founded as it is upon strict anatomical detail, it remains to discuss those cases of "colonial aggregations" in which the separate units are plainly recognisable, as in zoophyte, sea-mat, and tapeworm. Such cases will be found to differ not in kind, but in degree only, from the higher colonial organisations we have just described. The zoophyte and the highest animal are separated by a gulf not impassable or fixed, when the aid of broad generalisation in comparative anatomy is invoked. For there are, firstly, gradations and stepping-stones connecting the two extremes; and there exists, moreover, a general principle of development whereby the differences between the colonial nature of the higher and that of the lower form may be aptly expressed. Thus the sponge illustrates a case in which the colonial nature of the highest organisms is plainly enough foreshadowed. A sponge or a hydra advances but a tithe of the developmental journey which a bird or quadruped has to pursue; and as a result of its early arrest on the developmental pathway, its component units evince but little elaboration on their primitive and animalcular state. If a sponge is a mass of amœbæ, as to its living parts, it exists in this simple condition because there was no further need for a more intimate relationship between its various units. The fact, already mentioned, that two fresh-water sponges, placed in contact, unite into one, shows the ill-defined nature of the individuality in a case like the present, where the units are merely placed in apposition, so to speak, and united simply by the common skeleton they elaborate. In a zoophyte (Fig. 189), which is in reality but little removed above the sponge in the animal series, development and its attendant conditions—whatever these latter may have been—have together produced units as thoroughly distinct as those of the sponge, but nevertheless connected in the work of nourishing and repairing the colony. In the "sea-mats" (Fig. 190) we see a stage of colonial development in an animal form which more nearly approaches the condition of the higher animals, but which likewise lacks all the intimate features of connected interests seen therein. The "sea-mat" colony is an aggregate of units each of which we have seen to be perfectly independent, save for external connections, of its neighbour units. There must thus exist a certain and not distant parallelism between a "sea-mat's" constitution and that of higher beings; inasmuch as both are colonial, and in both the units exist in a relative but by no means corresponding degree of independence.

Analogies are thus plentiful enough in showing us the stages which intervene between the dependence and connection of the units in higher life, and the comparative independence of those in lower life. But the cases of the Naïs or river-worm (Fig. 192), as well as those of the plant-lice and bees, show us plainly enough the amazing possibilities of highly organised animals becoming "colonial" organisms, even with complete separation and detachment of the units of the colony—which, however, in the case of the bees, as "social" insects, is again reconstructed in the institution of a co-operative life and existence. In the Naïs, we see illustrated a tendency towards repetition of "zooids," which may be viewed as leading towards an appreciation of the manner in which an originally jointed animal—itself colonial in one sense—advances towards the condition of the plant-lice and bees with free and separate units. It is not more surprising, we may repeat, to find the insect-individual with its separated and detached units, than to discover in the higher bird or quadruped the same colonial structure, but one likewise which is closely combined and intimately related as to its elementary parts. The possibilities of life are facts, indeed, which in the present case cut both ways; demonstrating, even if leaving the main collateral facts unexplained, how in the higher spheres of animal society, the independence of an animal colony may perfectly co-exist with the interdependence of its original units.

But there exists for the biologist a final and authoritative court of appeal in the matter of the origin of the colonial constitution and its modifications, in the facts and teachings of development. The general tendency of any organism undergoing development is, as we have seen, one leading it towards differentiation and division of its primitive and originally simple substance. Even in the lowest confines of life we witness this tendency towards segregation and multiplication of its parts. The gregarina (Fig. 183, *a*) exhibits such a process, and the early stages of all living beings are marked by the segmentation and division of the germ. Conversely, as we ascend the scale of being, we witness as marked a tendency towards concentration and amalgamation of at least the superficial aspects of the organism. The higher animal or plant is not so markedly colonial as the lower organism. Externally, indeed, there may be no trace in the higher organism of compound nature; whilst, as we have seen, the intimate constitution of its tissues fully reflects its colonial constitution. Then, also, arrest of the process of development seems to increase the tendency towards the colonial organisation. The tapeworms (Fig. 191) may, on good authority, be regarded as animals whose development has been arrested at an early stage of that process. We may readily enough conceive that, but for such arrest, these animals might have progressed towards that higher type of worm structure—seen in leech, naïs, or earthworm—in which the separate joints practically represent the elements of a colony in close and inseparable union. Thus a leech or earthworm, like the higher animal, is "colonial." It represents the transition stage between a low colony with loosely aggregated units, such as the sponge typifies, and the higher colony in which the units have become closely merged together, as in the bird or quadruped. This view of the intermediate place of these animals is not merely supported by their position in the animal tree, but likewise by the fact that each apparently closely connected joint of a true worm accurately represents the structure and functions of every other joint of the body—save, indeed, the specially modified segments of head and tail. The worms and their allies thus become interesting in our eyes, from the fact that they present us with examples of that degree of development which, whilst leading towards union of the original units of the organism, yet leaves their identity sufficiently distinct to permit their ideal separation and the realisation of their originally colonial nature, through the exercise of a free philosophy.

Thus we again conclude that the primitive and earliest condition of structure in the living series is the "colonial" and compound condition. We arrive at this conclusion from a survey of the teachings of development, which shows us, firstly, that everywhere the germ in its earliest state tends to division and multiplication. Secondly, we note that many organisms, such as the lower colonies of protoplasmic forms, or even the mere primitive sponges themselves, remain permanently in a colonial condition, which would naturally enough represent permanent arrest of development in the early stages of egg-development. Thirdly, we learn that arrest of development, even at a later stage, may produce the colonial organisations of higher types. This latter view meets the case of the tapeworms and of the true worms likewise. In the latter, as represented by the Naïs (Fig. 192), we see the hereditary tendency towards colony-making reproduced as accurately in the buddings of new individuals from the parent-body, as in the perpetual budding of the zoophyte. Last of all, we see in the highest animals the same innate and fundamental constitution on the basis of the colony. The human frame, morphologically viewed, is a collection of cell-colonies, produced by segregation of more primitive collections of units, and primarily, if the story told by development be true, by the modification first of one cell, and secondly of one original series of cells.

The fundamental constitution of the living worlds thus appears to be of colonial nature. It remains for us to discover how the compound constitution has merged into these united and single personalities we regard as the highest members of the animal and plant series—in a word, how the "colony" has become the "individual," the highest type of which we recognise in ourselves. If varying conditions have operated to produce the diverse constitutions of animals and plants we see displayed before our waiting eyes to-day, we may justly assume that a more complex series of causes than we are able to determine, is responsible for the origin of those higher natures of which we ourselves form part. Yet here and there clues to the understanding of the problem are not wanting in the considerations which the study of even lower grades of life disclose to view. The apparently single nature of the germ from which high and low organisms alike spring may best be explained, perhaps, on grounds connected with the husbanding of vital power, and on the idea that the apparent unity and singleness of the germ naturally reproduce the constitution of the single cells or units of the compound organism from which they spring. The egg or germ, in a word, reflects in its first stage the constitution of the particular unit from which it was derived. In its secondary stage it repeats the colonial condition of which its parent-unit formed part, and the features of which it is destined in due time to reproduce.

As, however, we survey the fields of animal and plant existence, we discover plainly-marked tendencies of development which fully account for the advance from the true colonial constitution of zoophyte, tapeworm, and social insect, to the marked and apparently single personality of higher life. The higher we rise in the organic series, the less marked becomes the tendency to devote the energies of life to the perpetuation of the *species* or *race*; and the more perfectly do the powers which concentrate, ennoble, and advance the *individual* interests become developed. It is a self-evident fact that in lower life much of the bodily energy is occupied with the development of new individuals, or, in the case of an animal colony, with increase of the colonial membership. One has but to glance at the zoophyte-races to find clear proof of this latter statement. Imitating the plant-creation in the fulness of their vegetable growth, the tribes of zoophytes—and the tapeworm-race with its millions of ova, and indefinite reproductive power as well—unquestionably possess as their chief end the perpetuation of the race. How changed is the physiological prospect in higher existence! There the energies are devoted to the improvement, sustenance, and development of the individual. There is less devotion to the species as compared with what obtains in lower forms; and the colonial interests, whilst still represented and conserved, are limited in their scope and direction to the development of new tissue-matter. The higher animal, in short, is not obviously "colonial" in the sense that a zoophyte or a "sea-mat" is compound, because the energies and forces, as well as the material, which in the lower being reproduces readily the form of the organism, are devoted to other functions. Life in the lower and compound organism is made up of one common interest, namely, the increase of the colony and species. In the higher animal, life becomes a far more personal matter, and its aims are more distinctly individualised. Existence in the colonial zoophyte is passed, so to speak, in marriage and giving in marriage; and the interests of the race are bound up in the work of its own extension. In the higher organism, individual interests and the life of the single organism occupy the greater part of its energies, so that, to use an expressive dictum, "the organism is like a society in which everyone is so engrossed by his special business, that he has neither time nor inclination to marry."

FIG. 199.—DAISY.

There is abundant illustration at hand of the view that the cultivation of individual interests destroys, by concentration of energy, the colonial organisation. Such an opinion finds its confirmation in the details of higher animal existence, and in the disappearance of those powers of bodily separation after injury which characterise lower life. The organic republic or colony, in which every unit is as good as its neighbour, is typically and perfectly represented in the zoophyte. But this thoroughgoing republicanism is as impossible of continuance in higher physical existence and in spheres biological, as it is found to be incompatible with the political development of nations. That is to say, as, in the life political, here and there special developments cause men to shoot ahead of their neighbours and to distance their competitors in the struggle for existence by individual strength and excellence, so in the life biological, there is the same tendency to development of individual faculties and powers over the common interests, and the same conversion of the colonial organisation into the concentrated structure and functions of the individual organism. In the plant-world there is a similar tendency towards concentration as the concomitant of higher life. The colonial nature of many of the lowest plants (e.g. *Volvox*), which consist of aggregated masses of protoplasm, is undoubted. But in the highest plant-life also (Fig. 197, 1), the colonial nature is far more strongly marked than in many animals of by no means the highest grade. Where the leaf-type (*e e*) repeats itself indefinitely, where bud resembles bud, where there is witnessed the gradual transformation of leaf-type into flower-type (*h*), and of flower into the full fruition of plant-life, there is presented to our mental view an exact picture of the budding zoophyte (Fig. 197, 2), with its series of similar units (*ee*). Here and there these units become modified, now for this function, now for that; but exhibiting the closest parallelism with the plant, in that its reproductive bodies (*f*) are but modifications of the ordinary members of the colony; as the flower, in turn, is but the last term in the modification of the leaf. Thus, as Asa Gray well puts it, "In the ascending gradation of the vegetable kingdom, individuality is, so to say, striven after, but never obtained; in the lower animals, it is striven after with greater though incomplete success; it is realised only in animals of so high a rank that vegetative multiplication or offshoots are out of the question—where all parts are strictly members and nothing else, and all subordinated to a common nervous centre; it is fully realised only in a conscious person."

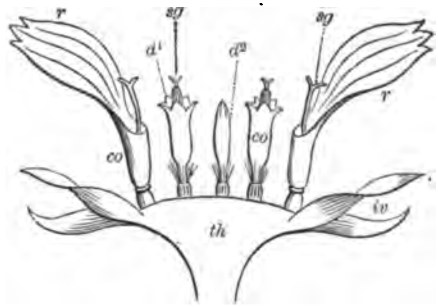


FIG. 200.—SECTION OF DAISY.

Yet, whilst the plant-world has not as a whole advanced towards the higher phases of individuality, we may discern here and there within its limits, signs of that universal progress which evolution postulates and which biological research reveals. Here and there we witness among plants a progression from the prevailing colonial organisation towards singleness of type. The *Composite* race of plants derive their name from the fact that each flower of the order is not a single flower, but a collection of florets. A thistle (Fig. 203) or a daisy-head (Figs. 199 and 200), for example, is not one flower, in the sense in which a buttercup or lily is single, but is an aggregation of small stalkless flowers (200, *co*, *co*) closely packed together on one main stalk. If we examine the thistle-head, we shall find it to consist of numerous little flowers (203 *c*, *c*), of similar appearance, each containing the essential organs and parts seen in other single flowers. In the Centauries of our waysides and cornfields, we witness the same composite structure of the flower-head; but here, the outermost florets (202, *a*) of the "head" have begun to develop into petal-like organs, and have lost their stamens and pistils. The Centaury, in other words, has developed the beginning of a low individuality; it is losing its completely compound nature, and is advancing towards the singleness of type of ordinary flowers. Thus, in *Centaurea nigra*, these outer florets vary in size; they may resemble the inner ones in size, or may be larger, and they may want both stamens and pistils. In another species (*C. scabiosa*), stamens and pistils never occur in the outer florets; and in *Centaurea cyanus* (Fig. 202) likewise, these florets (*a*) are useless for reproduction, and are passing towards the type and function of ordinary petals. So also in the familiar dandelions (Fig. 201), we may witness a stage in advance of the thistle. For whilst the latter plant has its florets similar and inconspicuous, the dandelion (Fig. 201) has added to its similar florets the bright corollas, which serve to render this wayside plant so conspicuous to insect eyes as well as to our own perception. When the dandelion appears with its outer florets expanded, while the inner florets have still to unfold, the flower bears no inconsiderable resemblance to the ordinary type of single flower. Far more advanced, however, towards the individuality of other plants, are the marigolds, daisies (Figs. 199, 200), and their allies. Here the likeness of the single flower deceives the non-botanical observer into supposing that each daisy in reality corresponds to each buttercup or primrose in its constitution. For the outer florets of the daisy and marigold have developed, as those of

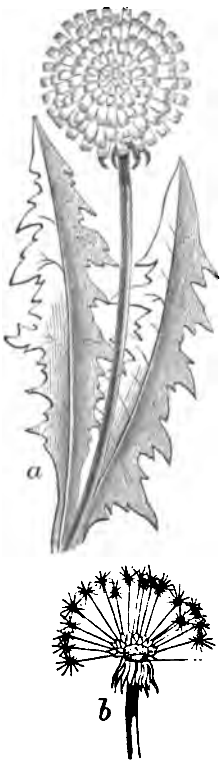


FIG. 201.—DANDELION. *b*, Ripe flower-head.

the centauries (Fig. 202, *a*) are developing, into long petal-like organs (Fig. 200, *r*). Moreover, these outer florets are losing the reproductive organs they still possess in the dandelion. The stamens have disappeared in the outer white and yellow flowers of the daisy and marigolds respectively, leaving the pistil alone represented (Fig. 200, *r*, *sg*); whilst the yellow central florets (d^1 d^2) possess both stamens and pistil, and are therefore the true producers of seed. It is foreign to our present inquiry to notice how this arrangement of the flower parts, by placing the brightly coloured parts on the outside, imparts to these plants their conspicuous nature, and thus, by attracting insects, gives them a very marked advantage in the struggle for existence, through securing more frequent fertilisation. How or why this greater attractiveness has been acquired is immaterial. That which is all-important for us to note is, that concurrently with a conspicuous dress, there is being developed in such flowers as the daisies and marigolds a return to that singleness and individuality which was in all probability once represented in their race, before the work of aggregating once separate flowers to form one flower-head had begun. The thistles remain types of a true flower-colony. The dandelions and centauries lead us from the thistles with similar florets to an intermediate type, wherein we see being developed those features which, along with abortion of part of the outer florets, are causing the compound flower to assume the dress of its simple neighbour; whilst in the daisies specialisation has advanced a step further, and has developed a very marked likeness to the simple flowers around. If these modifications progress in the future as in the past, we may naturally expect that the "floures white and rede" of Chaucer, and their allies, will develop a still more marked individuality, and will leave the lower compound nature of their race further and further behind.

FIG. 202.—*Centaurea cyanus*, or CORN BLUEBOTTLE.

It may be, lastly, interesting to note that the crowding together of flowers on a "flower-head," seen in the daisies and their neighbours, is susceptible of explanation through a study of the modifications and gradations witnessed in the arrangement of flowers on their axes. From cases in which we find flowers situated each on a distinct stalk of its own, as in the *Corymb* and the *Umbel* (Fig. 204) of botanists, to the condition of the "flower-head," we can pass by easy gradations. If we cut short the stalks of the umbel, and thus crowd the separate flowers on the end of a common stalk, we obtain a fair idea of the possible origin of a flower-head by abortion of the flower-stalks of an umbel or allied floral arrangement. The fact that such crowding of flower-heads on a common stalk is not limited to the *Compositæ* or Daisy-tribe, but occurs in other plant-orders, argues powerfully in favour of its acquired nature as the result of common modifying conditions. Thus a head of clover essentially repeats the condition of the thistle or centaury. We can obtain a fair idea of the effect of modification by the disappearance of flower-stalks, if we look at a simple umbel, seen in the cherry (Fig. 204, *a*), or a compound umbel, seen in fool's parsley (Fig. 204, *b*), and, by crowding the flowers together, *minus* their stalks, imagine their growth in one stalkless group to represent the "flower-head" of the daisy or thistle.

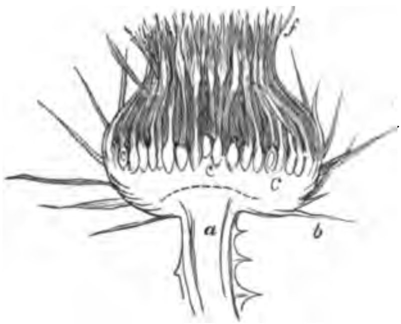


FIG. 203.—HEAD OF THISTLE SHOWING NUMEROUS FLORETS.

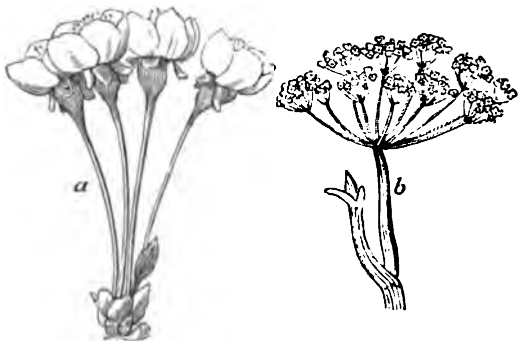


FIG. 204. *a*, SIMPLE UMBEL OF CHERRY; *b*, COMPOUND UMBEL OF FOOL'S PARSLEY.

Summing up our studies in organic individuality, we may say that, firstly, the original and primitive condition of all organic beings is a colonial condition. This phase is exemplified, primarily, in the segmentation of the egg and in the cell-multiplication of plant-germs; two features of so universal occurrence that we may lawfully claim for them a great importance in the evolution of the organism and a high antiquity in the history of living things. It is likewise imitated in the so-called asexual reproduction of the lowest animals, represented by the gregarinæ and amœbæ. A second conclusion that follows from the teachings of development may be expressed by saying that this tendency to division of substance is most typically seen in lower organisms, where, as exhibited in the sponges, zoophytes, and their allies, the constitution of the individual is undeniably compound, and where its advance is marked merely by the multiplication of new types of colonial and connected units. We discover, thirdly, that the tendency to degradation and retrogression may likewise plainly develop the compound and colonial state. It is highly probable that the tapeworms, the ordinary worms, and even Articulate animals themselves, illustrate cases in which a primary development of like segments or colonial units through arrest of growth, and through simple bodily division and repetition of like parts, has paved the way for succeeding modification of the colonial type. If the evolution of the centipedes, insects, spiders, and crustaceans from a lower worm type be accepted as proved, or even as probable, the characteristic features of these animals must have been fundamentally derived from those colonial tendencies we see exhibited in the worms of to-day. A fourth conclusion teaches that the plant-world is markedly colonial even in its highest types. The vegetative repetition of bud, leaf, and flower is simply a pure indication of colonial constitution exhibited in all that perfection of detail which has escaped the more forcible modification of the animal series. A fifth inference directs attention to the essentially colonial constitution of even the highest animals, as exhibited in their cellular structure, and more especially in the independent constitution of many of their component cell-elements. And a sixth and final conclusion is deducible from our studies—namely, that concentration of structure and function, and the metamorphosis of the colony into the true individual, is at once a cause and a result of the progressive tendency of life at large. The higher we rise in the scale of being, the more united and specialised do structure and function become. Such a tendency is represented, as we have seen, even amongst plants, in which the colonial and compound type tends to resolve itself into the simpler and more individualised phase. At the same time, we must recognise that, despite the functional unity of the highest animals, there remains in their relative cellular independence the traces of a colonial constitution, once universal, and still linking them by real as well as by transcendental bonds to lower and antecedent phases of existence.

The topic of the personality of living beings, like most other biological subjects, relates itself more or less indirectly with matters personal and ethical which are far beyond the scope of the present study. But it is permissible, in a closing sentence, to remark that many of the characteristic traits of the life of the higher animals, including man himself, may perchance be traceable to an unconscious perpetuation of habits and customs which find their beginnings and germs in the lower colonial organisms whose history has just been discussed. The nervous acts of man and the higher animals generally, for instance, convince us that many of the functions of the brain, and the automatic actions of the body depending on the independent constitution of our nerve-centres, may be legitimately explained by referring them, as regards their origin, to an originally colonial constitution, and to a primitively colonial ancestry. Even a glance at the serial repetition of the bones (or vertebræ) in the spine of man or other backboned animal, eloquently enough testifies to the apparent colonial constitution of these forms. There is a striking analogy, which has not escaped biological notice, between the arrangement of these segments in the Vertebrata and the similar disposition of parts in the Articulata or worm and centipede-type. However the Vertebrate's serial arrangement has originated, it may perhaps be held as legitimate evidence of compound nature; just, indeed, as the colonial nature of Vertebrate tissues demonstrates that nature in another fashion. And so, also, with other phases of human relationship and functions. As the various detached buds of a hydra, or the free-swimming buds of a zoophyte, are still part and parcel of the individual constitution, or as the plant-lice and bees, apparently of distinct personality, are in reality only parts of the connected colony, so, in the sphere of human relationships, the origin of the tribal connection or of the family constitution—itself the most expressive of all human institutions—may perchance be found to exist in germ-form in the hidden transcendental bond which the philosophy of the lower animal individuality discloses. The deep-seated affections and relationships which, collectively, we term the "family" and "society" respectively, may have had their first beginnings in the connected series of interests which even the zoophyte-series discloses to view. In other words, we are constituted as we are, gregarious, social, and ethical, because we are physically "colonial" by constitution, and because in our origin we are essentially of colonial and compound nature. And if such a thought be regarded as too improbable for realisation, it should be borne in mind that our structural beginnings themselves are of the lowliest and simplest description. If the structural germs of the highest life begin, as they certainly do, under an animalcular guise, is it overstepping the possibilities of natural facts to suggest that the social traits and characteristics to which that germ attains may likewise have had a lowly and material beginning? Such an idea, so far from possessing any elements of impossibility, is grounded on a rational basis—namely, on that opinion which teaches that community of origin may, and often does, entail similarity of results. Sufficient has been said to show that in human existence reign many of the colonial traits of lower spheres. And if, perchance, some dim echoes of such lowly traits may linger in the scientific mind when contemplating the highest existence of all, the mind will regard such similarity as founded upon no chance basis, but as having originated from that continuity of cause and effect which runs unbroken through the warp and woof of the universe of life.

XIV.

THE FERTILISATION OF FLOWERS.

FEW subjects, if any, are better calculated to awaken a lively interest in the investigation of natural laws and the phenomena of life at large, than the study of those processes of development whereby the races of animals and plants retain their hold upon the world, and maintain a continuous and unbroken round and cycle of existence. In such studies, more than in any others, we seem to gain near glimpses of Nature's ways and methods in fashioning the varied universe of living beings; whilst the lessons such topics are well calculated to enforce respecting the order of nature as a whole, form not the least important result of these investigations. The study of even the most commonplace object may, under the newer phases of research, be made to yield an amount of "sweetness and light" for which we might be wholly unprepared. The day of the Peter Bells, and of uninquiring moods and tenses, if not altogether a thing of the past, is happily already in its twilight stage. The schoolboy, with a primer of botany in hand, understands things at which the previous generation simply wondered. And even if the results of botanical study may occasionally be expressed by the hackneyed Wordsworthian idea of thoughts beyond tears, the modern student of plant-life has ample reason to congratulate himself on having attained the mastery of many ideas, which in past years were included under the poetic category of "expressive silence." The primrose still grows by the "river's brim," in truth, but it is no longer merely a yellow primrose. On the contrary, the flower is in greater part understood, the mechanism of its life is well-nigh completely within our mental grasp; and, best of all, its study has led in the past, as it leads even now, to the comprehension of wider ideas of nature, and more extensive views of plant life, than those which formerly met the gaze of the wayfarer in scientific pastures. The appreciation of what is involved in part of the life-history of a primrose may thus serve as a starting-point for more extensive research into the phenomena of plant-fertilisation at large; and this latter topic, in its turn, falls naturally into its proper niche in teaching us plain lessons respecting the manner in which the wide domain of life is regulated and governed.

By the "fertilisation" of a plant is meant to be indicated those actions or processes in virtue of which those little bodies named "ovules" developed in the seed-vessel (Fig. 205, *p*) become "seeds," and through which they are fitted to develop into new plants. The unfertilised ovule is incapable of producing a new plant. When set in the ground it would simply decay, as if it were a leaf or other detached and dead portion of the plant-economy. When,

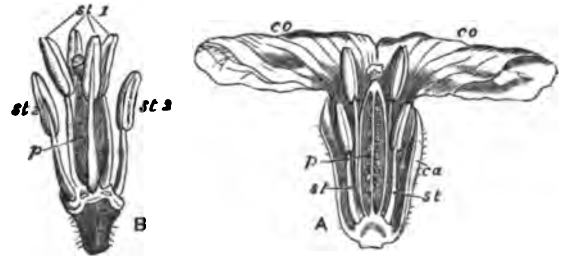


FIG. 205.—WALLFLOWER.

on the contrary, it is duly fertilised, the ovule, becoming the "seed," has become possessed of the powers and properties in virtue of which it is capable of evolving the form of the parent-plant from which it was derived. So much for the very necessary botanical distinction

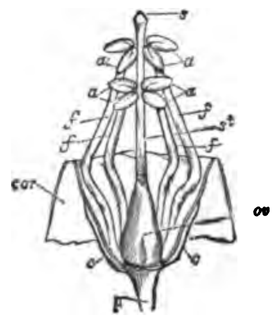


FIG. 206.—FOXGLOVE.

FIG. 207.—SNAPDRAGON.

between "ovule" and "seed." The process of fertilisation is thus seen to be that on which the continuance of plant-existence depends. More closely regarded, it is known to be that which is capable under certain conditions of giving origin to new races or varieties of the plant-species. When the horticulturist, taking the pollen from one species or variety of plant, applies this fertilising matter to the ovules of another variety or species, the characters of the two different races are combined and united in the "hybrid" progeny. Our gardens and conservatories—and, as we shall strive to show hereafter, the natural plant-creation at large—have benefited immensely in beauty from a knowledge of the changes in colour, form, and size, which this "cross-fertilisation" may produce. For instance, the finest of our rhododendrons are crosses in which the characters of Indian and American species have been thus blended. The union of the common heartsease with a large-flowered foreign pansy, has produced a new stock in which the excellences of both species are found. The pelargoniums of our conservatories represent hybrid stocks and varieties, which cross-fertilisation and cultivation have together produced from the small-petaled species of South Africa. Such results, among countless others, would seem to suggest that beneath the subject of cross-fertilisation, or even underlying that of ordinary fertilisation, there lies hid a mine of knowledge respecting the causes which have wrought out the existing variety of plant-life. For the plain and unfettered understanding of the subject in its less technical phases, or to lay the foundations of knowledge respecting an interesting field of natural-history study, no better subject could be selected than the history of even the commonest flower—such as a primrose. Rightly comprehending what is included in the phases of primrose-life, we may hope successfully to read some of the more abstruse problems presented by the wider aspects of plant existence at large. "The ruthe primrose that forsaken dies," and the "cowslips wan that hang the pensive head," afford us delight even when we are living in all the simplicity of botanical ignorance. It is not too much to say that their systematic study may lead to the higher delights and more cultured joys included in the knowledge of some phases of natural law and in an understanding of the hows and whys of living nature.

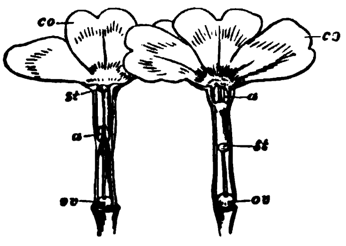


FIG. 208.—PRIMROSES.

The elementary botany of a primrose is a matter of few words. Like every other perfect flower, it consists of four parts or circles of organs placed one within the other. Outside, we perceive the circle of fine green leaves, which we name the *calyx*, each green leaf of this organ being named a *sepal*. In the primrose or campanula (Fig. 214), the sepals are united, although in many other flowers, (*e.g.*, buttercup and wall-flower) (Fig. 205, *ca*), we should find them free and separate. The calyx of all flowers is, for the most part, coloured green, its obvious use being to form a protective envelope for the other organs ot the flower. Within the calyx, we descry the *corolla* (Fig. 208, *co*). This is the circle of *petals* or leaves which, *par excellence*, we call the "flower," because it constitutes in the vast majority of flowers the bright and showy portion thereof. A flower might botanically or physiologically be perfect enough minus its corolla; although the eye, missing the bright petals, would be apt to regard such a plant as wanting the first and chiefest element of the blossom. The common nettle, for instance. appears to possess no "flowers" in the popular and accustomed sense of the term; but when we examine the plant, we readily discover that it possesses parts corresponding to the flowers (Fig. 209) of other plants. In the greater nettle, the flowers of one plant are essentially different (in that they possess "stamens" (Fig. 209 *s s*) alone)

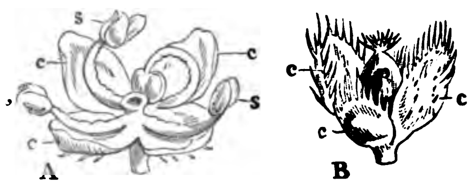


FIG. 209.—NETTLE-FLOWERS.

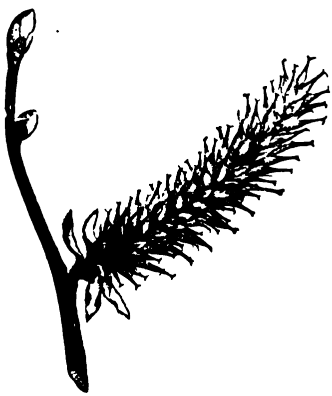


FIG. 210.—FEMALE OR PISTILLATE FLOWERS OF WILLOW.

FIG. 211.—MALE OR STAMINATE FLOWERS OF WILLOW.

from those of another plant (which possess "pistils" (*p*) only). But in the lesser nettle, or in the oak, these distinct flowers (Figs. 212, 213) are found on one and the same plant. No vestige of colour appears in either, however; and when we study the flowers in question, we find that a corolla is wanting, although a calyx (Fig. 209, *c*) is present. Again, in the willow, which, like the greater nettle, has its stamens and pistils (Figs. 210 and 211) *on different plants*, there appears to be no "flower" in the ordinary sense of the term; and the calyx as well as the corolla is found to be wanting in these trees.

The *stamens*, just mentioned, form the third set of organs proper to the perfect flower. Looking at buttercup, wall-flower (Fig. 205, *st*), saxifrage (Fig. 215) or campanula (Fig. 214), we readily see the stamens. They exist as stalked organs (Fig. 214, *ss*), each con-

FIG. 212.—MALE OR STAMINATE FLOWERS OF OAK.

sisting of a stalk or *filament* (Figs. 216, 217, *st*), and a head called the *anther* (*a*). The head is hollow and contains the fine yellow dust termed *pollen*, which, at the time of ripening, is usually found scattered conspicuously about the interior of most flowers. The fourth and central set of organs found in the flower constitute the *pistil* (Figs. 214, 215, and 218) or seed-producing structure. This organ is composed of one or more parts called *carpels*. Each carpel consists in turn of a lower distended part called the *ovary* (Fig. 218, *ov*), within which the ovules are produced; of a neck or filament, the *style* (*st*); and of a head borne on the style (*sg*), and named the *stigma*. The style or stigma may be absent; but in the great majority of flowers both parts are present, the ovary being however, the essential part of the pistil. In the "head" of a poppy, for instance, there is no style; the bulk of the "head" consisting of the ovary containing numerous seeds, and the flat cap or lid representing the "stigma" of the poppy-pistil. As a final observation concerning the parts of the flower, it may be noted that the separate pieces, or "carpels," of which a pistil is composed, may either be free and distinct, or closely united and adherent to each other; whilst a second fact of importance in the general description of flower structure, consists in the declaration that the ripe and mature pistil is the *fruit* in botanical parlance. True, there may, as in the strawberry (Fig. 219), be found united to the ripe pistil certain other parts which constitute the edible and desirable portion of the plant. The true pistil in the strawberry consists of the little yellow carpels, (Fig. 219, *f*), usually called "seeds," which are imbedded in the fleshy mass of the fruit formed by the expanded top of the flower-stalk. But the æsthetics of taste must be neglected in the strict descriptions

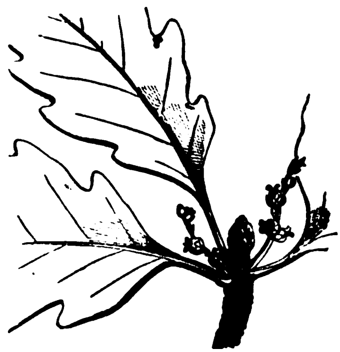


FIG. 213.—PISTILLATE FLOWERS OF OAK.

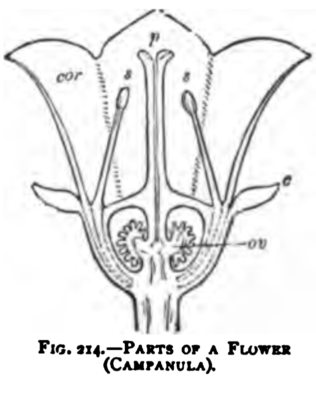


FIG. 214.—PARTS OF A FLOWER (CAMPANULA).

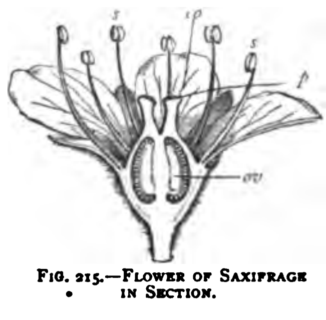


FIG. 215.—FLOWER OF SAXIFRAGE IN SECTION.

of science; and that alone is the "fruit," in the eyes of the botanist, which is formed by the ripened pistil, or central organ of the flower.

All parts of the flower, it must be observed, are not of equal value in the eyes of the botanist. Those organs—stamens and pistil—which produce and elaborate the seed, are physiologically more important than the circlets or whorls of leaves which, in the form of calyx and corolla, surround and protect them. Yet the latter organs play their own part in the production of seeds, and in some cases serve as the actual means whereby special modes of fertilisation are primarily induced and carried out. As the sequel may show, indeed, the

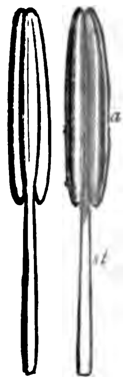


FIG. 216.—STAMENS OF IRIS.

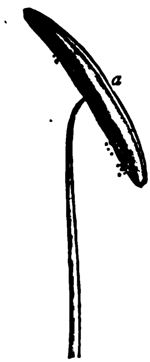


FIG. 217.—STAMEN OF AMARYLLIS.

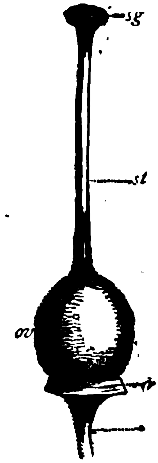


FIG. 218.—PISTIL OF CHINESE PRIMROSE.

calyx and corolla—which in previous years were deemed mere "floral envelopes," being credited, as such, with a merely protective function—have largely risen in importance in the estimation of the botanical world; since on the form, colour, size, &c., of the corolla especially, largely depend the working of those mutual relations which have been formed between the insect-world on the one hand, and the world of flowers on the other. Peculiarity of a corolla implies, botanically, as a rule, peculiarity of fertilisation; and the importance of the blossom becomes plainly apparent to us when we discover that in place of the somewhat limited function formerly assigned to it by the unscientific philosopher—namely, that of affording delight to man by its beauty—it subserves the truer and more logical mission of aiding materially the increase of the race to which it belongs, and of which it forms such a characteristic part.

FIG. 219.—STRAWBERRY.

Turning to the primrose for practical illustration of the foregoing precepts, we may readily enough find in its structure plain instruction in the build of the flower. The circle of green leaves placed outside the yellow blossom is, of course, the calyx. This green cup consists of five leaves or sepals united in the primrose, but free and easily separable in the buttercup or wallflower (Fig. 205, A, *ca*). The blossom or corolla (Fig. 208, *co*) of the primrose exhibits similarly a united condition of parts. We can tell that it consists of five petals, or leaves, by counting its prominent lobes or projections. When we tear the corolla in two, longwise, we readily perceive the five stamens (*a*), which, however, in the primrose, exhibit a somewhat peculiar position, in that, instead of arising from the end of the flower-stalk, like the other organs of the flower, they spring from the sides of the united petals (Fig. 208). If we seize the corolla of a primrose by its upper portion, and pull it gently upwards, the entire blossom with its attached stamens will become detached from the flower-stalk, leaving the calyx and pistil on the latter organ. Then tearing or cutting away the calyx, we may be favoured with a clear view of the pistil itself, seated on the extremity of the flower-stalk. In the pistil (Fig. 218) we behold a body consisting below of the swelled or rounded structure already mentioned, and named the ovary (*ov*). This being cut across, is seen to contain numerous seeds or ovules, as the case may be, arranged around a central pillar named the *placenta*. From the upper part of the ovary arises a long stalk, the style (*st*) of the pistil; and the style, in its turn, is capped by a flat head, the stigma (*sg*). In the pistil of the primrose we therefore see the three typical parts, already noted as constituting the central organ of the flower. The pistil in this case, it may be remarked, consists of five carpels, so closely united that it is only by the aid of the "law of symmetry" (or that demonstrating the general correspondence of numbers in the flower-parts) that we can determine its composition. Five is the ruling number in the calyx, corolla, and stamens. Hence we conclude that the pistil of the primrose in its composition will conform to the type of the other whorls of the flower.

The physiology of the flower naturally follows the consideration of its structure. Living action, in other words, forms the natural corollary to living machinery or structure; hence we may fitly inquire into the manner in which the work of fertilisation is carried on in the economy of the primrose. Leaving for after treatment, the more special features of fertilisation, the general scope of the function whereby, as we have seen, the immature "ovules" are converted into "seeds"—each capable of developing, when planted, into a new primrose—may be readily appreciated. The stamens, each possessing as its essential part the *anther* or head (Figs. 216 and 217, *a*), develop the yellow dust, or *pollen*, as one of the two elements concerned in the work of plant-development and reproduction. Sooner or later, the anthers of the stamens open in one way or another so as to allow the pollen to escape; and, viewed under the microscope, the pollen-grains are seen to vary greatly in size and form in different species of plants. The grains of pollen may be round (Fig. 220) or oval in form; in the evening primrose (Fig. 222) and fuchsia, they are of triangular shape; in the hollyhock and melon (Fig. 223) they are spinous; and in the orchids they are united to form masses (Fig. 221) called *pollinia*.

The pollen-grains being conveyed to the stigma (Fig. 218, *sg*) of the pistil, they are there attached by the aid of a glutinous secretion, which

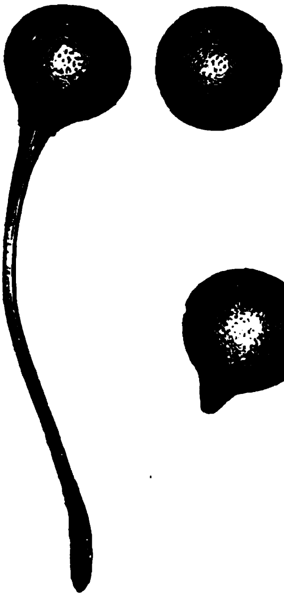


FIG. 220.—POLLEN-GRAINS EMITTING POLLEN-TUBES.

FIG. 223.—POLLEN-GRAIN OF MELON EMITTING CONTENTS.

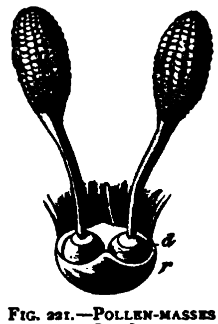


FIG. 221.—POLLEN-MASSES OF ORCHID.

FIG. 222. POLLEN-GRAIN OF EVENING PRIMROSE (MAGNIFIED).

may likewise be credited with a specific influence on the pollen-grains, in that it appears to stimulate the curious development they next evince. This development consists in the rupture of the outer of the two layers of which each pollen-grain consists. Through the ruptured outer coat, the inner layer begins to grow in the form of a long tube—the *pollen-tube* (Fig. 220)—which penetrates the tissue of the style (Fig. 224), and grows downwards to reach the ovules contained in the ovary. In some plants, the pollen-tubes emitted from one pollen-grain may be very numerous, although as a rule only one tube grows from each grain.

Now, the essence of fertilisation (*i.e.* the production of a "seed" fitted to produce a new plant) appears to consist in the contact of the pollen-tube with the ovule, so that the viscid matter called *fovilla*, contained within the pollen-grain, may be applied to the structures of the ovule. The most important part of the ovule itself is a small cellular body called the *nucleus*, enveloped in a couple of coverings. The hollow interior of the nucleus is named the *embryo-sac*, and an opening

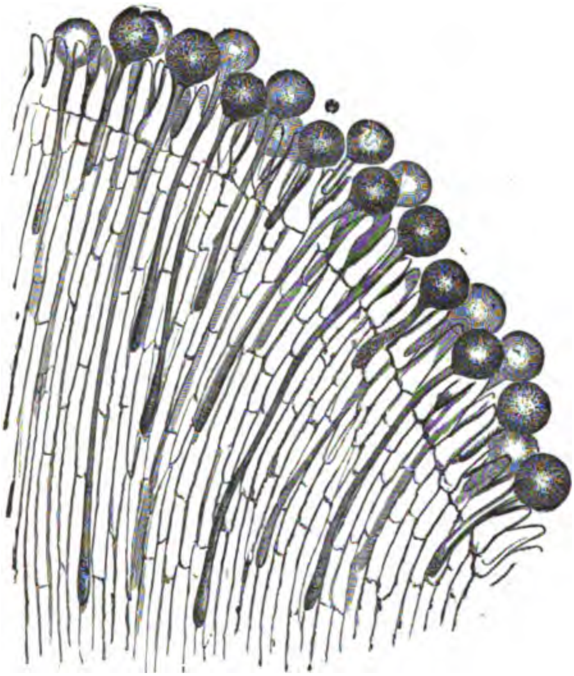


FIG. 224.—POLLEN-TUBES OF DATURA PENETRATING THE STYLE (MAGNIFIED).

called the *micropyle* also exists in the coats of the ovule. Through this opening the pollen-tube passes, gaining admittance thereby to the nucleus, and thence to its hollow body or embryo-sac, wherein the fovilla, or contents of the pollen-grain, are discharged.

Such is the work of fertilisation, and such are the processes in virtue of which the ovule becomes the seed. As the result of these processes, the "embryo," or young plant, is duly formed within the embryo-sac, and thus, even before the seed is planted, development has already proceeded to a certain extent. In the seed of a pea or bean (Fig. 225), for instance, we readily perceive the rudiment of the stem (*p*), the beginning of the root (*r*), and likewise the first appendages or "seed leaves (*c*)," which that stem will develop.

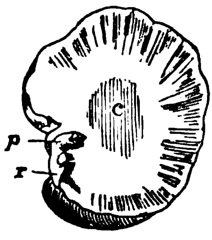


FIG. 225.—SECTION OF BEAN.

The process of fertilisation, thus described in its essential nature, involves in the case of certain plants some curious details, the mere mention of which may stimulate to an independent research into botanical lore. Thus, often the pollen-tubes may require, from the length of the style of the pistil, to grow to a large relative extent. In the crocus, the pollen-tube requires to grow to a length of three inches before it can reach the ovules in the ovary. The number of pollen-grains in flowers may be apparently in excess of all reasonable proportions—a fact to be accounted for on the well-founded idea that the pollen of a flower is not usually limited to that particular flower's wants, but may be destined to serve for the fertilisation of others of the same species. In the great flowered cactus (*Cactus grandiflorus*), Morren says there are about 500 anthers, 24 stigmas, and 30,000 ovules. Assuming that each anther contains 500 pollen-grains, this will give a total of 250,000 grains to each flower; and the interval or space between the stigma and the ovules of this plant is about 1,150 times the diameter of the pollen-grains. Nature appears exceedingly lavish in her development of pollen. If the Tennysonian aphorism that—

> Of fifty seeds
> She often brings but one to bear,

be true—as it unquestionably is—the apparent over-production of pollen-grains is even more remarkable, although we have to take into account the fact just noted, that the development of pollen bears a relation rather to the species and race, than to the individual necessities of the plant. Otherwise, Fritz Müller's estimate, that in a single flower of *Maxillaria* there are developed 34,000,000 grains of pollen, must present itself as an inexplicable fact of botanical science. Even the wheat-plant produces about 50 lbs. of pollen to the acre. The pollen of the cone-bearing plants (*Coniferæ*), such as the firs, larches, pines, or that of the catkin-bearers (*Amentiferæ*), is often borne through the air as showers of yellow sulphur-like dust. This dust, falling in regions where the elements of botany are unknown, cause perturbation amongst the unlearned, and result in the penning of epistles to "Mr. Editor" by way of inquiry whether or not the sulphureous shower is a portent or grave omen of coming disaster or impending peril.

The phenomena of fertilisation just detailed, take place in our primrose, as in all ordinary plants; but whilst there exists a uniformity in the details of this process, there is also found a literally amazing variety in the fashions whereby pollen is conveyed to the stigma of the pistil. Once placed in the natural position for fertilisation, the growth of the pollen-tube follows as a matter of course. But the means whereby the pollen reaches the stigma, and the various fashions in which it may gain its ultimate position on the pistil, constitute features in which are bound up some of the most important issues of plant existence. To rightly comprehend the bearing of fertilisation, a glance at our wallflower (Fig. 205), primrose (Fig. 208), foxglove (Fig. 206), or buttercup will suffice as a starting-point for further investigation. Within the primrose and the buttercup are situated, as we have seen, the two sets of organs—stamens and pistil—necessary to secure the production of seed and the continuance of the race. Hence it might form a very natural and reasonable inference, that the pollen from the numerous stamens of a buttercup flower should be used to fertilise the ovules of the pistil of that flower. Such a process—that in which a flower's own pollen is used to fertilise its own ovules—is termed "self-fertilisation." Looking at the vast majority of our flowers and plants, which possess each a perfect array of stamens and pistil, the normal course of things seems strongly suggestive of self-fertilisation. Hence, in the early days of botany, self-fertilisation was undoubtedly believed to be the rule of nature. Now, there can be no question whatever that "self-fertilisation" does occur in nature, but there is as little doubt that it is the exception, and not—as botanists from the days of Linnæus well-nigh to our own day have maintained—the rule, of plant life. There can be little doubt, for instance, that many small species of the buttercup order (*Ranunculaceæ*—e.g. *Ranunculus hederaceus*) are self-fertilised, because we find the stamens to arch over the pistil, and to shed their pollen on the carpels. In *Agrimonia*, in the same order, the stamens, at first curved outwards, curve inwards, so as to bring the pollen within easy reach of the stigmas. So, also, in a species of Malvaceæ (*Malva rotundifolia*), Müller has demonstrated that this plant is self-fertilised, since stigmas and anthers actually intertwine, and are thus placed in the most favourable position for the fertilisation of the ovules. Some species of *Geraniaceæ* (e.g. *Geranium pusillum*) are self-fertilising likewise; and many flowers belonging to the rose tribe (*Rosaceæ*), such as *Potentilla*, fertilise themselves.

It is a remarkable fact that in certain plants (*e.g.* many violets; *Lamium amplexicaule*; *Oxalis*, &c.) very small, inconspicuous, and closed flowers are produced, in addition to the ordinary conspicuous and, as we shall see, "cross" or insect-fertilised flowers. These closed flowers have been named "cleistogamous"—a term applied by Kuhn in 1867. They are self-fertilised, and produce numerous seeds; and their occurrence in the same plant along with cross-fertilised blossoms, may perhaps be best explained on the theory that, whilst the ordinary and less fertile flowers will afford to the plant the advantages and benefits which accrue from "cross-fertilisation," the "cleistogamous" flowers may be regarded as the normal means for the ordinary increase of the race. What the flower loses in variation by the sparing fertility of the cross-fertilised flowers, it may gain in the number of seeds which the cleistogamous flowers produce. Cleistogamous flowers likewise tend to economise pollen. Whilst 400 pollen-grains may serve the purpose of close or self-fertilisation in *Oxalis*, or even 100 grains in some violets, three-and-a-half million grains may be produced in the insect-fertilised flowers of the peony, and many millions in the case of wind-fertilised flowers, whose pollen, like that of the firs, has to be distributed over immense areas of land.

There appears, therefore, to be a proportion of plants in which the existence of stamens and pistil in the same flower—the normal condition of matters in ordinary plants—is meant to and does secure the fertilisation of the ovules by the flower's own pollen. Why, then, seeing that the presence of correlated stamens and pistils in each flower appears to be a common condition of plant life, do we assume that not self-fertilisation but the opposite process—*cross-fertilisation*—is the rule of nature? The reply to this query involves more than one important consideration. Let us briefly endeavour to find a convenient starting-point in the familiar flower which Peter Bell despised, and which, to minds of utilitarian type amongst ourselves, is but a primrose still, and "nothing more."

If we study the structure of the primroses we may gather in a bed of these flowers, it will be found that the blossoms obtained from one set of plants will vary in certain respects from the flowers of the other and neighbouring plants. There is no difference in appearance or in outward aspect between the primroses, because the differences referred to affect chiefly the position of the stamens and the length of the style (or "neck" of the pistil) in each variety. But we may readily discover that, selecting any one primrose plant, all the flowers of that plant will be either long-styled (Fig. 208 A) or short-styled (Fig. 208 B), and will not exhibit a mixture of the two varieties. "The two kinds of flowers," says Mr. Darwin, speaking of the long and short-styled cowslips, which form a closely allied species to the primroses, "are never found on the same individual plant;" and he also remarks that he has never met with any transitional states between the two forms growing in a state of nature. The cowslips and other allies of the primrose exhibit a like disposition of parts. Thus, when we slit one of the primroses longwise, we see that the stamens (Fig. 208 B, *a*) are placed high up on the petals or near the top of the corolla, and the style is comparatively short. In the other variety (Fig. 208 A, *a*), the stamens are placed far down within the tube of the corolla, whilst the style is so long that the stigma (*st*) appears to block up the entrance to that tube, and reaches to the top of the petals. Thus we speak of "short-styled" (B) and "long-styled" (A) flowers in primrose and in all other plants in which these conditions occur; whilst, popularly, the short-styled forms are called "thrum-eyed," and the long-styled ones "pin-eyed." Such a disposition of stamens and pistil also occurs in *Pulmonaria officinalis*, in *Linum perenne*, and in other plants, which are hence called *dimorphic*, *i.e.* having two forms of flower. And in some plants (*e.g.* Oxalis and the Spiked Loosestrife or *Lythrum Salicaria*), three varieties of flowers are known, and these latter are named *trimorphic* in consequence.

Returning to our primroses, we find that the pollen-grains of the two forms of flower differ in size. Those of the long-styled primroses (A) are smaller than those of the short-styled flowers. Mr. Darwin remarks of the pollen-grains of the latter flowers, that "before they were soaked in water, they were decidedly broader, in proportion to their length, than those from the long-styled; after being soaked, they were relatively to those from the long-styled as 100 to 71 in diameter, and more transparent." Mr. Darwin also compared these two forms of flowers in other respects. He found that the seeds of the short-styled flowers "weighed exactly twice as much as those from an equal number of long-styled plants," the short-styled being the more productive of the two forms. As final facts concerning the differences between the two varieties, it may be noted that the stigma or head of the pistil in the long-styled form is more distinctly globular and roughened on its surface than that of the short-styled primroses; whilst the stigma in each form stands nearly, but not quite, on a level with the anthers of the opposite variety.

What can be affirmed, as a matter of observation, to be the meaning and purpose of this diverse arrangement of stamens and pistils in these plants? Meaning it must have, and that one which is closely bound up with the history of the species. So indeed, it was found, when, through Mr. Darwin's researches, contributed to the Linnæan Society's Transactions in 1862, it was clearly demonstrated that the arrangement in question had reference to the *cross-fertilisation* of the primroses and of all other plants in which a like diversity of structure was found. Mr. Darwin then pointed out that the structure of the primrose was eminently adapted to favour the visits of insects as aids in procuring the fertilisation of the long-styled flowers by the pollen of the short-styled flowers, and *vice versâ*. Such an interchange of pollen is accomplished in a manner readily understood. Suppose that an insect —such as a humblebee—first visits a "long-styled" flower (Fig. 226, 2), drawn to the primrose in search of the nectar which this flower, the cowslip, and other members of the genus secrete in quantity. The proboscis of the bee will be thrust into the tube of the corolla, and in the act of nectar-gathering it will unconsciously dust its proboscis with pollen nearer the tip of that organ than the base. Suppose next that the bee, with its pollen-laden proboscis, flies to another primrose plant of the "short-styled" variety. The proboscis, inserted therein as before, will come into contact with the low-lying stigma, and upon this surface will be left the pollen which was gathered from the stamens of the long-styled flower. Thus interchange the first is accomplished. But when visiting the "short-styled" flower (1), the bee's proboscis, coming in contact with the stamens (placed at the top of the flower), is dusted near the base with short-styled pollen. Hence the next visit paid to a "long-styled" flower results in the placing of pollen from the short-styled flower upon the stigma of the long-styled primrose. The stigma of the latter is placed, as we have seen, at the top of the flower (Fig. 226, 2), and it is thus well calculated to meet the base of the bee's "tongue," which has been dusted with short-styled pollen. Interchange the second is thus accomplished, and the *cross-fertilisation* of the primrose race becomes a matter of well-nigh absolute certainty.

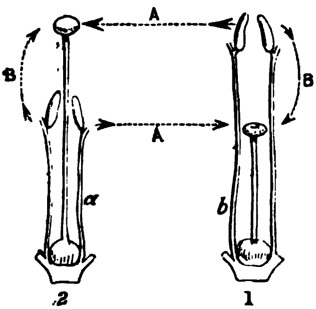


FIG. 226.
FERTILISATION OF PRIMROSE (*Darwin*).

As indicated in the annexed figure, from Mr. Darwin (Fig. 226), the "legitimate" (A) fertilisation is that which occurs when pollen from the long-styled form is placed on the short-styled pistil, and *vice versâ*. The "illegitimate" fertilisation (B) is self-fertilisation in either case; namely, through the pollen of either flower being placed upon its own stigma. Mr. Darwin's own words, applying to his observations on the cowslip (*Primula veris*), may be read with interest as applying likewise to the similar arrangement in the allied primrose. After noting that humblebees, and likewise moths, visit these flowers, Mr. Darwin says: "It follows from the position of the organs (anthers and stigmas) that if the proboscis of a dead humblebee, or a thick bristle or rough needle, be pushed down the corolla, first of one form and then of the other, as an insect would do in visiting the two forms growing mingled together, pollen from the long-stamened form, adheres round the base of the object, and is left with certainty on the stigma of the long-styled form; whilst pollen from the short stamens of the long-styled form adheres a little way above the extremity of the object, and some is generally left on the stigma of the other form." Mr. Darwin is also careful to note that "self-fertilisation" must occasionally occur in these flowers, through "an insect, in withdrawing its proboscis from the corolla of the long-styled form," leaving pollen from the flower on that flower's own stigma. Such a result will occur most frequently in the case of the short-styled flowers, as may be experimentally demonstrated, and small insects, such as those belonging to the genus *Thrips*, wandering aimlessly about within the flower may likewise be the means of inducing self-fertilisation. But, as if in anticipation of such defeat of her clear intent and purpose, we find a very significant observation brought to light in the fact that even if a flower's own pollen be placed on its pistil, *cross-fertilisation* may yet take place, inasmuch as pollen from a different form of flower seems to be capable of obliterating the effect of the flower's own pollen, "even," adds Mr. Darwin, "when this has been placed on the stigma a considerable time before." An experiment of very crucial nature supplies an instance of the prepotent effect of foreign pollen over a flower's own. On the stigma of a long-styled cowslip Mr. Darwin placed "plenty of pollen from the same plant." After a lapse of twenty-four hours he added pollen "from a short-styled dark-red polyanthus, which is a variety of the cowslip. From the flowers thus treated thirty seedlings were raised, and all these, without exception, bore reddish flowers; so that the effect of pollen from the same form, though placed on the stigmas twenty-four hours previously, was quite destroyed by that of pollen from a plant belonging to the other form."

The philosophy of primrose-existence can hardly be said to be in any sense comprehended through the mere knowledge of the contrivances which exist in that flower for the prevention of self-fertilisation and the favouring of the opposite process. On the contrary, the philosophy which carries with it the understanding and appreciation of the system and order of nature is only discernible when, firstly, we step forth more fully "into the light of things," and when, secondly, we discover, from such wider views of flower-life, the advantages gained and the ends served by the processes under consideration. Hence, for the present, we may turn with profit from the polity of a primrose to discuss some analogous feature in that wider realm of flowers to which the primrose and its kind may fitly introduce us. After such survey we may, with additional likelihood of arriving at just conclusions respecting the philosophy of plant-life, return to the Primula and its lessons once more.

It has been already remarked that "self-fertilisation" is the exception and "cross-fertilisation" the rule of plant-nature. At any rate, the cases where "cross-fertilisation" is obviously the process which by manifold contrivances nature seeks to further and effect, increase in number year by year. Although self-fertilisation does occur, and is a possibility even with normally cross-fertilised plants, yet the whole drift of modern botanical teaching tends towards the recognition of the mutual interchange of pollen betwixt related flowers as the normal way of plant-reproduction. Nor do the comparative results—to be hereafter detailed—of cross and self-fertilisation in the least degree vitiate these conclusions. On the other hand, every fact of botany dealing with ascertained results of the one method of fertilisation, as compared with those obtained by the other, testifies to the enormous gain, possible and actual, to the plant-creation through the effects of cross-fertilisation. The presence of so many different methods whereby this end is secured, constitutes an eloquent fact in favour of the supposition that the normal way of plant-life undoubtedly lies in the direction of pollen-interchange, as a necessity for energetic development and for the full fruition of the races and tribes of plants that people earth's firmament.

Within the limits of the present chapter it would be impossible to enter into the discussion of those peculiarities of insect structure which have been developed or modified in turn like the forms of flowers for the due performance of the work of cross-fertilisation. It may suffice at present to simply point out that the conformation of the legs of certain insects, as well as the form of the mouth-parts, and even the hairiness of body or the reverse conditions, all bear witness to special adaptation in different insects for the fertilisation of special flowers. Certain insects are known to confine their visits to special plants—some to one species of plant only; and probably, when this department of the subject is more fully and completely studied, the number of cases in which insect-visitation is of a rigid or exclusive kind, will be largely increased.

The two chief methods of cross-fertilisation, or, in other words, of flower-fertilisation at large, are thus: (1) by insects, or more rarely birds, snails, &c.; (2) by the *wind*; whilst (3) pollen may be floated *on water* from one plant to another, as in the case of *Vallisneria spiralis*. Botanists term plants fertilised by insects "entomophilous," and those fertilised by the wind "anemophilous." Some plants, *e.g.* common rhubarb (Darwin), and some species of Plantago (Delpino and H. Müller) exhibit an intermediate condition, in that they may be fertilised in either way. The wind-fertilised plants, as an "invariable rule," according to Darwin, possess small and inconspicuous flowers, whilst the insect-fertilised flowers, as might be expected, are conspicuous, or, if not brightly coloured, are strong smelling. Moreover, there are certain conspicuous differences between the pollen and its quantity, and between the form of the stigma, &c., in wind-fertilised and insect-fertilised flowers.

The pollen of the wind-fertilised plants is produced in far greater quantity than that of the insect-dependent flowers. Then, also, the former flowers open before the leaves are in full growth, in order that the clouds of pollen may gain easy access to the pistils; whilst their stigmas are usually branched and bending (*e.g.*, alder, wheat, &c.), so as the more readily to intercept and detain the pollen in its wind-flights. Allusion has already been made to the showers of pollen emitted by coniferous trees, and it may be added here that bucketfuls of pollen from conifers and grasses are occasionally swept off the decks of vessels off North American coasts; whilst North American lakes may be covered over a considerable area of their surface by the yellow pollen of the pines. Most of our cereals are presumably wind-fertilised; and the importance of light breezes in the early summer may therefore be a matter of consideration in respect of the full ears of autumn. Hooibrenk and Kœrnicke, in their practical suggestion, carried out in Belgium and Germany, of drawing a rope across the full-flowered ears so as to distribute pollen and cross-fertilise the plants, seem therefore to have imitated nature's method. The question of the wind-fertilisation of the cereals, it may be remarked, however, is at present an open one, since some botanists elect to believe that the wind-distributed pollen is simply the excess or useless pollen remaining after fertilisation has been accomplished; the actual agency in scattering abroad the fertilising dust being said to be the sudden extension and elasticity of the stalks of the stamens.

That cross-fertilisation is the rule of nature, is a fact amply demonstrated by the well-nigh endless contrivances in flower-structure, form, appearance, and function, through which the interchange of pollen is brought about. Let us briefly glance at the outlines of such a study. Allusion has already been made to cases in which a separation of stamens and pistil takes place as a normal condition of many plants. Such separation may proceed to the extent of placing stamens in one set of flowers, and pistils in another set on the *same* plant; or it may be illustrated by the more complete isolation of these organs, so that in the latter case we find all the flowers on one plant to be "staminate," and all the "pistillate" flowers to be borne on another plant. The lesser nettle, for instance, has its stamens and pistils in different flowers on the same plant, as also have the oak (Figs. 212, 213), melon, cucumber, maize, hop, hazel, carex, &c. The greater nettle, on the other hand, bears on one plant none but staminate flowers, and on another plant none but pistil-bearing flowers; whilst hemp, willow (Figs. 210, 211), the variegated laurel (*Aucuba Japonica*), palms, &c., also illustrate the complete separation of stamens and pistil. Other conditions, more or less uniting these dispositions of the stamens and pistil, may be found in flowers. In a daisy—which is a collection of flowers—we find the outer or white florets to possess pistils but no stamens, and the yellow and central florets to possess both stamens and pistil. We can readily discern that all such arrangements secure pollen of essentially foreign kind for fertilisation. Self-fertilisation is, in fact, impossible in such cases as those just described; and some very curious facts are found in botanical archives concerning the difficulties experienced in obtaining "seeds" where one of the necessary elements—usually the pollen—for fertilisation was absent. The variegated laurel presents a case in point. The first specimen of this species introduced from Japan was a pistillate or female plant, and could produce ovules from its flowers, but no "seeds"; inasmuch as, no pollen from another and staminate plant was forthcoming. The plant was largely reproduced from slips alone until within comparatively recent years, when staminate plants being imported, pollen was then forthcoming for the production of seed. The Egyptians have long been in the habit of bringing palm-branches bearing stamens from the desert, in order to fertilise the domesticated pistillate or fruit-bearing palms grown at home. This necessary process was frustrated in 1808, when the French occupied Egypt, and when the stamen-laden branches could not, in consequence of foreign invasion, be procured. In the well-known *Vallisneria spiralis*, a water-plant of Southern Europe, which, like the willow and palm, has stamens and pistils on separate plants, the pistillate flowers are borne to the surface at the proper period by the relaxing of a spirally coiled stalk on which they are supported. The stamen-bearing flowers, on the contrary, are borne on short stalks, and, becoming detached therefrom, float to the surface of the water. There they scatter their pollen, which reaches the pistillate flowers, and the latter being fertilised, are drawn by their stalks once more beneath the water, where the seeds mature and the fruit in due course ripens.

The present is perhaps a fitting stage of our inquiries to remark that the tendency towards cross-fertilisation in nature is nowhere more strongly marked than in cases where a plant is utterly infertile with its own pollen, but perfectly fertile when impregnated with pollen from another plant of the same species, or, in some notable instances, from an entirely different species of plant. Species of passion-flowers have been found sterile with their own pollen, although "slight changes in their conditions, such as being grafted on another stock, or a change of temperature, rendered them self-fertile." More extraordinary still, however, is the knowledge of the fact that the pollen of some orchids actually acts like a poison if placed in what one would have deemed the most natural position for it, namely, on their own stigmas. Such facts as these entirely alter the former conceptions of a "species," as a group the members of which were fertile *inter se*, but infertile with members even of nearly allied species; and such knowledge supplies a wholesome corrective to the theory that species are separate, independent, and distinct entities both as to origin and after-relations.

If nature contrives by such means to effect cross-fertilisation, there exist ample fields for the demonstration of a like result in other and

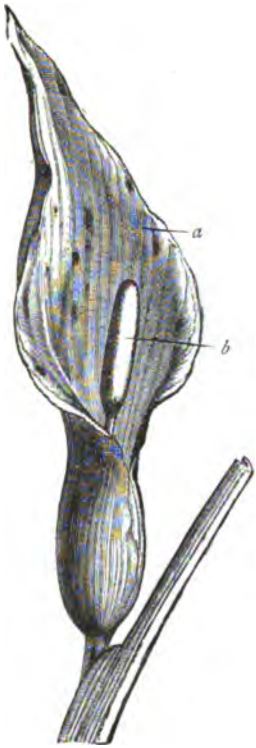


FIG. 227.—ARUM, OR CUCKOO PINT.

FIG. 228.—CARNATION, SHOWING THE RIPE PISTIL

very varied fashions. In a very large number of flowers, for instance, the stamens ripen and discharge their pollen before the pistil is ripe, or the ovules ready for fertilisation. In other cases, but more rarely, the pistil ripens before the stamens. The former case is illustrated by most species of geraniums, pelargoniums, by harebells, and other *Campanulaceæ* (Fig. 214), by many umbelliferous plants, by carnations

(Fig. 228), sweetwilliam, and allied plants, and by many plants of the daisy and dandelion type (*Compositæ*). The latter case (of the earlier ripening of the pistil) is illustrated by the rib-grass (*Plantago*) of the roadsides, by the cuckoo pint (*Arum*, Fig. 227), and other plants. One or two familiar illustrations will suffice to show how clearly and effectually nature carries out her intention of securing cross-fertilisation by different periods of ripening in stamens and pistils.

The pink, or carnation (Fig. 228), in its first condition, exhibits the case of a plant possessing stamens alone. These organs ripen, discharge their pollen (which is carried by insects to flowers whose pistil may then be ripe), and then die away. After the stamens, and with them all chances of self-fertilisation, have disappeared, the pistil matures, and its style and stigma develop fully (Fig. 228). It is then fertilised by foreign pollen—that is, by pollen from a pink whose stamens are at that period in full development. So also is it with thyme, whose stamens ripen first; and with the Canterbury bells, harebells, and like flowers. In the campanulas (Fig. 214) anthers and pistil are closely related before the flower opens; and when the anthers discharge their pollen, it is shed upon the style or stalk of the pistil; and only after the stamens have shrivelled up and their pollen has been carried away by insect agency to other "bell-flowers," does the pistil develop fully, and its three conspicuous stigmas open out so as to receive pollen from another and, at that period, pollen-producing flower. In cases like the preceding, therefore, it is evident nature does not intend that the flower's own pollen should fertilise its ovules.

The opposite case occurs in the Plantago, where the elegant little pistils ripen first, and where the stamens do not mature until fertilisation of their flower has been accomplished by foreign pollen. In the cuckoo pint (*Arum*, Fig. 227) there is also witnessed the ripening of the pistil before the stamens. Every one knows this plant, with its sheathing leaf (*a*), and the central stalk (*b*) bearing the "flowers." The anthers are placed above the stigmas; hence it would seem, at first sight, as if nature intended that their pollen should fall downwards and fertilise the plant's own ovules. But the pistils ripen long before the stamens. When the latter are mature, the pistil has been already fertilised. Hence the pollen, it is evident, must be intended for fertilising other pistils of the species, unless, indeed, we can maintain that nature, like Homer, "sometimes nods." The pollen in this case falls to the bottom of the sheathing leaf, where it might well seem to be lost entirely to the outer world. Small insects, however, in due course arrive upon the scene. Entering the cavity of the leaf readily enough, on the principle of *facilis descensus Averni*, they find the reverse process, *revocare gradum*, to be impossible. By an arrangement of stiff hairs, pointing downwards, which they readily enough brush aside on entering, they are prevented from escaping out of the flower. Hemmed in by this natural *chevaux de frise*, as in an eel-trap, we may find inside an Arum a hundred or two small insects in durance vile. Here, however, they find nourishment in the honey-secretion, and here they, in due time, work out nature's will, in that they become laden with the discharged pollen. So that when the opposing hairs shrivel and wither away, the insect-crowd disperses itself, and its units, undeterred by reminiscences of their imprisonment, entering other Arums in which the stigmas have just ripened, duly cross-fertilise the latter.

Risks of fertilisation being omitted altogether are not lost sight of in the economy of nature, and such contingencies are often duly provided for in remarkable ways. In *Myosotis versicolor* (Fig. 229), for instance, there is an evident intent to prevent self-fertilisation, from the fact that the pistil (*st*) projects far above the stamens (*a*) in the young flower (A), and is therefore a likely object to be touched by an insect which has come from another "Forget-me-not," as this flower is often named. But such an arrangement, dependent on insect visitation, might be rendered futile if no insect happened to alight on the flower. In due time, however, the corolla is seen to increase in length; as it grows upwards, the stamens (*a*) are carried upwards (B), until, in due time, they attain the level of the stigma (*st*), and by discharging their pollen upon it will fertilise the pistil, if it has not already undergone that process from a foreign source. Such a contrivance appears tantamount to the declaration, on the part of plant-nature, that, although cross-fertilisation is sought and preferred, yet self-fertilisation is better than none.

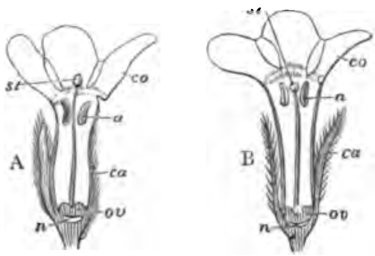


FIG. 229.—MYOSOTIS IN ITS EARLY (A) AND LATER STAGE (B).

Besides the means just noted, there exist a large number of expedients in flowers for securing fertilisation; these latter contrivances relating to the form and shapes of flowers, to the special positions of its organs, and to adaptive details of flower structure. The polity of a primrose, in the peculiar situation of its stamens and pistils, as adapted to secure cross-fertilisation, falls under this latter division of floral expedients; and so, also, would all these peculiarities of stamens whereby the discharge of pollen in a fashion adapted to avoid self-fertilisation is secured. In some flowers (e.g. *Parnassia*), as the five stamens ripen one after the other (before the pistil, as it happens), each anther is laid back downwards, so to speak, on the stigma or top of the pistil, so that the pollen escapes by the side farthest from the stigma, and self-fertilisation thus becomes well-nigh an impossibility. But even the form and shape or colour of a corolla or blossom may be adapted either of itself, or when associated with other expedients, to secure cross-fertilisation in especial conjunction with insect aid. It has been pointed out that every flower of peculiar shape is cross-fertilised by insects. As notable instances of this fact may be cited the peas, beans, dead nettles (Fig. 230), sage (Fig. 235), salvia (Fig. 232), orchids, the peculiar shape of whose flowers, as well as the special arrangements of stamens and pistil, are correlated in the most exact positions to compel insects to visit special parts of the flower, and thus to ensure the exact performance of the work of cross-fertilisation. Even the distribution of colour on a flower, and the particular spots or dashes which attract our notice, are guides and fingerposts directing insects to the honey. Sprengel, of old, called these special colour-guides *maculæ indicantes*, and Mr. Darwin remarks, that Sprengel's ideas seemed to him "for a long time fanciful." But the fact that these markings are most commonly met with on unsymmetrical or irregular flowers, the entrance into which would be more likely to puzzle and confuse insects than the apertures of symmetrical flowers, weighs in favour of dashes and spots of colour being truly directive in function.

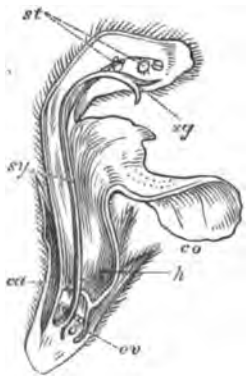


FIG. 230.—DEAD-NETTLE IN SECTION.

Mr. Darwin further remarks that, in the common pelargonium, the marks in question, borne on the two upper petals, are clearly related to the position of the "nectary" or honey-store of the flower; for when the flowers vary so as to become regular, and lose their nectaries, the marks disappear. When the nectary is in part undeveloped, only one of the upper petals loses its characteristic mark. It is true that humblebees are known to bite through the petals of flowers, and to surreptitiously suck the honey through the apertures thus made, and even hive-bees learn to utilise the holes made by their larger brethren. But, notwithstanding this latter fashion of securing stolen sweets—a method indicative of a certain power of development in bee-intellect—there can be little doubt that originally to bees, as at present to insects who walk in the trodden paths of their race, the colour-marks and special hues of flowers are serviceable, as Mr. Darwin remarks, in guiding insect visitors rapidly and without loss of time to the store of sweets, and in thus enabling them to visit a larger number of flowers in a given time than would otherwise be possible. Sir John Lubbock remarks, that he did not realise the import of these markings in flowers until he saw how much time bees lost, if honey which has been put out for them is even slightly moved from its usual place. Whilst it forms an allied subject of the most interesting description, to speculate upon

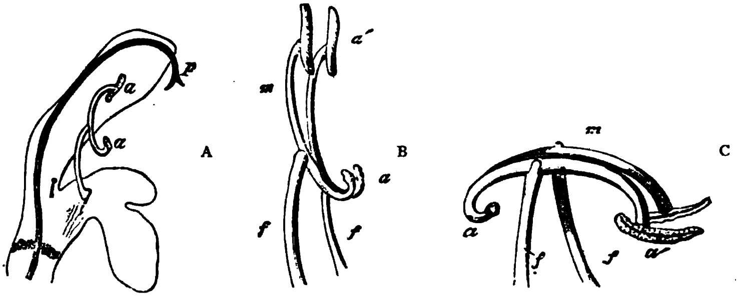


FIG. 231.—FLOWER AND STAMENS OF SALVIA.

the remarkable changes in colour which some plants undergo, and which, like the times of opening and closing, are doubtless related to the visits of insects. Thus, we know of some flowers (*Hibiscus*) which are white in the morning, of a pale rose hue at mid-day, and exhibit a bright rosy red colour in the evening. Many flowers change their hues as the petals wax old and tend to fall off; and

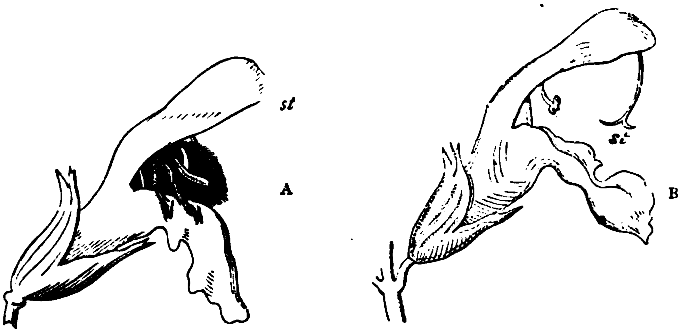


FIG. 232.—FERTILISATION OF SALVIA.

that such alterations of hue have a reference to insect-visits, and attract, it may be, insects of different tastes and structure at different periods, is by no means a far-fetched speculation. The presence of bright colours in flowers has been shown to bear an important relation to fertilisation, and necessarily, through this latter process, to the development of such species of plants. Bright hues are, as a rule, associated in flowers with a faint development, or even a want of scent. Insects being attracted by one quality or the other, the presence of scent would be useless where colour is well developed. If we compare such flowers as pelargoniums, convolvulus, pansy, fritillary, &c., which are conspicuous and bright tinted, but scentless,

FIG. 233.—SECTION OF FUCHSIA.

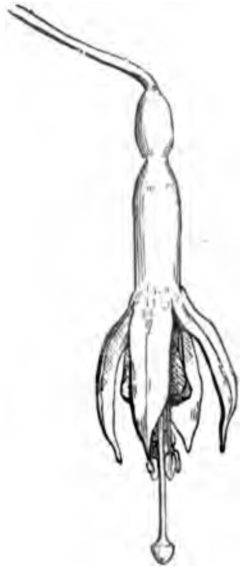


FIG. 234.—FUCHSIA.

with the primrose, lily of the valley, rose, and hyacinth, which are not so conspicuous, but emit powerful odours, we can realise the principle of nature's economy in avoiding over-lavish provisions for insect-attraction. The correlation between flower and insect is even more strongly marked, however, when we discover that flowers which are fertilised by night-flying moths are usually of white colour, so as to appear conspicuous at night, and may further emit their odour only or chiefly at night. Such flowers as Daphne and Hesperis—obscurely coloured, as it happens—attract insects solely by their powerful odour. Nägeli's experiment of scenting artificial flowers with essential oils was followed by the attraction of insects "in an unmistakable manner."

The description of a few of the most typical cases in which cross-fertilisation is found may fitly conclude the more exact consideration of the present topic, and preface the abstract philosophy which directs attention to the bearing of the facts of fertilisation on the constitution and regulation of the world of life at large.

FIG. 235.—FLOWER OF SAGE.

FIG. 236.—FLOWER OF PEA DISSECTED.

A very interesting mechanism for effecting cross-fertilisation is seen in the case of flowers which, like the peas, beans, and their leguminous neighbours, present a very characteristic form of blossom. These flowers possess ten stamens (Fig. 237), nine united to form a bundle, and one remaining single. The flower is peculiar in that it consists of one very large petal (Fig. 236, *a*), behind or above, two at the sides or "wings" (*b b*), and two united to form the boat-shape "keel" (*c*) below. When an insect alights on the side petals or "wings" (Fig. 237, *al*), the keel (*c*) is thereby pressed downwards. The pollen of the stamens (*st*) and the tip of the pistil are made to project, so as respectively to dust the insect's breast with pollen, and to receive therefrom the foreign pollen gathered previously from another flower. Sprengel himself noticed that the union of the stamens favoured this conjoined action. When the weight of the insect's body is removed, the stamens and pistil resume their normal position. If, as Sir John Lubbock remarks, "the two ends of the wings (in a sweet-pea) be taken between the finger and thumb, and pressed down so as to imitate the effect produced by the pressure of an insect, the keel is

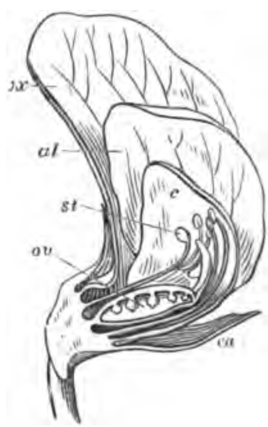


FIG. 237.—SECTION OF PEA.

depressed with the wings, while the pistil and stamens are thus partly uncovered." In the bean, when the wings are similarly pressed down, the stigma of the pistil, and then the "beard" of the style, laden with pollen, project from the keel, which is of coiled conformation. When a bee exercises the necessary pressure, the pistil of the bean will first strike its body and become fertilised by fresh pollen, whilst the pollen-laden style of the flower will, secondly, leave fertilising matter on the bee's body for application to the pistil of another flower.

A dead-nettle (Fig. 230), with its irregular flower, presents a favourable and readily understood example of the manner in which a special form of flower is adapted for the special insect which cross-fertilises it. A bank of dead-nettles is to humblebees what a country-fair is to juveniles, in that it presents the insects with a store of sweets specially intended for their delectation. In shape, the sage (Fig. 235), or dead-nettle flower, as everyone knows, exhibits a wide mouth, bounded by a very much arched upper lip, whilst a divided lower lip is also conspicuous enough. The green cup-like calyx has its sepals united, whilst the very irregularly shaped corolla is composed of united petals. There are four stamens—two long and two short—the fifth stamen of botanical expectation being abortive. The stamens are peculiar in position, inasmuch as they lie along the arch of the petals (Fig. 230, *st*), instead of surrounding the pistil. The style is very long, and forked at its tip (*sg*), and it moreover depends below the anthers as in fuchsia (Fig. 233). The honey for which the bees visit the dead-nettle is situated far down within the flower, and if we make a vertical section of the corolla, we shall find a circle of hairs (Fig. 230, *h*) placed inside the petals at their lower portion. Now, in what special fashion is the mechanism, thus described, brought into play in the fertilisation of the dead-nettle tribe? The reply may be found in a simple study of a dead-nettle on a warm summer's day, when insect-life and the blossoming of flowers together seem to attain the acme of activity and development. The bee approaches the flower, and finds in the lower lip of the blossom a convenient door-mat on which to alight. Here the insect gains a *point d'appui* for the movement of the proboscis, which probes the depths of the corolla so as to reach the nectar, and easily thrusts aside the circlet of stiff hairs presenting an impassable barrier to a less robust as well as uninvited insect guest. The acts of the insect, in so far as the work of honey-getting is concerned, end thus. Meanwhile, however, it has likewise been performing its unconscious part in the fertilisation of the flower. The position of the stamens under the hooded petal has been noted. Such a position assures two results—firstly, that the stamens shall be brought in contact with the bee's body; and secondly, that the pistil shall likewise touch the insect in order that foreign pollen, obtained from a previously visited dead-nettle, shall be deposited on the stigma. The stigma, as we have seen, depends below the anthers. Hence it must be the first object with which the bee comes in contact. Fertilisation by the foreign pollen is thus secured before the stamens have dusted the insect with the flower's own pollen. As Dr. Ogle has pointed out, the position of the stamens doubtless facilitates in a marked degree the proper placing of pollen on the insect's body. If the anthers had lain side by side, the bee's head might have been dusted on parts which do not touch the stigma as the insect enters the flower; whilst even the eyes of the bees might have become disadvantageously covered with pollen. There is, in short, the closest possible correlation between the structure of the flower and the form and size of the insect which fertilises it.

Such correlation is exhibited in, if anything, an increased degree in the genus *Salvia*, belonging to the dead-nettle order (*Labiatæ*), also including the sage (Fig. 235). Salvia (Figs. 231, 232) attracted the notice of Sprengel—Rector at Spandau—who, in his "Das entdeckte Geheimniss der Natur im Bau und in der Befruchtung der Blumen" ("The Secrets of Nature in the Structure and Fertilisation of Flowers"), published in 1793, was one of the first to direct attention to the fact that nature's law was "cross" and not "self-fertilisation"—or, as he himself expressed it, "nature does not desire that any complete flower should be fertilised by its own pollen." It is interesting to note that a species of *Salvia* (*S. splendens*) occurring in the New World appears to be cross-fertilised through the agency of humming-birds; these fairy-like birds thus discharging in this case the functions of the insects to which some species approach so nearly in size. The trumpet creepers (*Tecoma radicans*) and trumpet honeysuckle (*Lonicera sempervivens*) are probably fertilised by moths and by humming-birds as well.

In *Salvia officinalis* (Fig. 231, A), the general form of which closely resembles that of the dead-nettle, the stamens ripen before the pistil; and as, moreover, the stigma (*p*) is placed above the anthers (*a*), self-fertilisation is an impossibility. When, however, the stamens have shed their pollen, they shrivel up, and the pistil as it ripens develops the stigma, so that it elongates, curves downwards, and thus assumes a position (Fig. 232, B, *st*) in which it cannot escape contact with the back of the bee entering the flower (Fig. 232, A). The insect's back, it may be noted, is exactly that region which the ripe stamens in a younger and necessarily different flower will have dusted with foreign pollen. But the economy of *Salvia* includes yet other appliances for more effectually securing fertilisation by the insect. There are but two well-developed stamens (Fig. 231, B) in the flower. These organs have widely separated anther-cells (*a*, *a'*); and when in an undisturbed condition, each stamen is seen to consist of a stalk (the *filament*) (*f*), to which another and movable stalk (the *connective*) (*m*), bearing an anther-cell at each end, is attached. Only one of these anther-cells (*a'*) is fully developed in each stamen. The connective (*m*), like a swing-bar, can be pushed backwards on its axis so as to bring the fully-developed or upper anther-cell (*a'*) to a horizontal position (Fig. 231, C). Such a result is actually brought about by the bee. Thrusting its head into the flower in the search for nectar, the insect pushes before it the lower end of the swing-bar, and thus brings the upper end of the bar with its ripe anther (*a'*) in contact with its back (Fig. 232, A). This latter region is thus dusted with pollen, and when the insect flies to another Salvia flower in which the pistil is ripe, the stigma (Fig. 232, B *st*), as we have seen, will in due course receive the pollen through contact with the back of the bee.

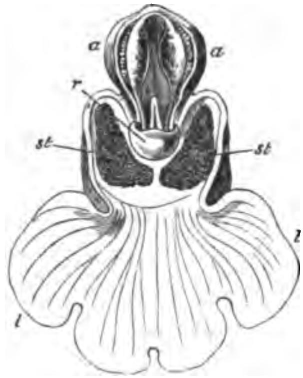


FIG. 238.—ORCHID FLOWER.

A single paragraph only is permissible regarding the curious details connected with the fertilisation of the Orchids, which possess

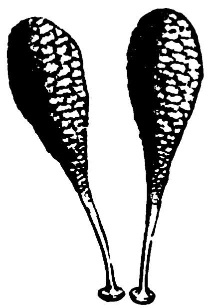


FIG. 239.—POLLEN MASSES OF ORCHID.

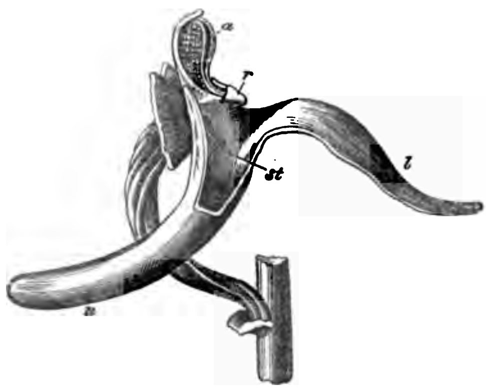


FIG. 240.—SECTION OF ORCHID FLOWER.

flowers (Fig. 238) of markedly irregular shape. The lip (*l l*) in such a flower as *Orchis mascula*, a common British species, is very broad; whilst the nectary to which bees desire admittance is extremely long (Fig. 240, *n*). The pollen forms two club-shaped masses (Figs. 239, 240 *a*), each adherent to a disc (Fig. 221, *d*), which in turn lies within the ***rostellum*** or cup (*r*). When touched, the rostellum breaks across, and thus allows the two glutinous discs (12, *d*) to become exposed. When a bee visits this peculiar flower, it pushes its proboscis into the nectary (*n*) for the sake of the honey contained therein. At the same time, the insect comes in contact with the discs of the pollen-masses (Fig. 239), these masses becoming adherent to the insect's head. A pencil pushed into an orchis detaches the pollen-masses after the fashion of the insect's unconscious act. At first, the pollen-masses remain erect like two abnormal horns on the insect's head; but gradually they assume a horizontal position, so that the insect cannot fail to charge the next orchid-pistil it enters with the pollen-masses. The stigma, or top of the pistil (Fig. 238, *st*, *st*), is so placed in these flowers that pollen-masses borne on a bee's head are certain to strike this surface, and thus fertilise the contents of the ovary. It is probable that as each pollen-mass consists of several packets of pollen-grains, one mass may contain material enough to fertilise several flowers; each stigma, through its viscid surface, detaching sufficient pollen from the mass for its fertilisation. The admirable adaptation of flower to insect and insect to flower, thus witnessed, is in no detail better exemplified than in the fact that the pollen-mass at first retains a vertical and then assumes a horizontal position in the insect's head. So long as the pollen-mass is vertical, fertilisation is impossible; and hence the vertical position persists so long as the bee is engaged in visiting the flowers of the plant from which it has derived pollen-masses. Thus self-fertilisation is prevented; so that, as Sir Joseph Hooker puts it, by the time the horizontal position of the pollen-mass is assumed, "the bee has visited all the flowers of the plant from which it took the pollen, and has gone to another plant."

To enter into further illustration of the contrivances through which the fertilisation of flowers is secured would be to encroach on the province of the technical and practical botanist. Such details are "writ large" in the pages of every botanical text-book. In the works of Mr. Darwin—and especially in the "Fertilisation of Orchids"—the reader anxious for further details may find a perfect encyclopædia of facts constituting a veritable romance of botanical science. It, however, remains to us in the present instance to point out the plain meaning of these virtually marvellous adaptations of the plant-world to the work of cross-fertilisation, and to note, as far as possible, the bearing of such a study upon the order of nature regarded as a harmonious whole. It is a perfectly legitimate supposition that if cross-fertilisation forms, as we have seen, such a prominent feature of plant-life, that life must, in some very plain and obvious fashion, benefit therefrom. And further, as plant-life is but a part of organic nature, we may feel perfectly justified in supposing that the conditions and results which cross-fertilisation tends to evoke and produce, will harmonise in their tendency and direction with the course of events through which the living universe has been and is being moulded, developed, and evolved.

To the question, "Why does cross-fertilisation appear to be favoured by nature over self-fertilisation?" a plain reply is at hand in a comparison of the results which accrue from each of these processes. Mr. Darwin's laborious researches on the comparative fertility of various species of plants when self-fertilised and cross-fertilised, supply an answer to the foregoing question, by showing that in every respect the cross-fertilised flowers yield more seeds, and give rise to a stronger and more numerous progeny than the self-fertilised. The reader who consults Mr. Darwin's "Forms of Flowers" will find himself supplied with ample data in proof of the advantages of cross-fertilisation. In the primrose, for instance, when short-styled and long-styled flowers were crossed in what Darwin calls "legitimate union," the result was invariably to produce a larger number of seeds than when each form was fertilised by its own pollen. Out of 12 long-styled primroses fertilised by short-styled pollen, 11 good capsules (or ripe pistils) were produced, with an average of 66·9 seeds per capsule; whilst 21 long-styled flowers, fertilised by long-styled pollen, produced only 14 capsules, with an average of 52·2 seeds per capsule. The cowslip gave a similar result; and the tendency towards greater vigour of offspring when cross-fertilisation is employed, appears to be of the most general kind. In some plants, indeed, cross-fertilisation is absolutely essential for the mere continuance of the race; so that this method of seed-production is not merely accidental or advantageous, but absolutely necessary for the continuance of the race. Most of the orchids illustrate this state of matters. The presence of humblebees is well-nigh an absolute necessity for the continuance of the heartsease (*Viola tricolor*); and the well-known case of the clovers may be cited as highly characteristic of the benefits developed through cross-fertilisation. Twenty heads of Dutch clover, protected by Darwin from bees, yielded no seeds: whilst twenty heads growing exposed as in a state of nature, yielded 2,290 seeds. One hundred heads of red clover protected from bees were absolutely sterile; a second hundred exposed yielded 2,700 seeds. The scientific demonstration of the interdependence of living beings becomes in this fashion perfectly clear. Carried out to its ultimate results, such demonstration becomes sufficiently startling. British brain and sinew depend (according to a foreign estimate) on home-fed beef; whilst the quality of that nutriment is said to be dependent upon the clover on which the ox subsists. But clover owes its continuance to humblebees;

humblebees in turn are killed by field-mice, whilst cats extirpate the rodents. As old maids conserve the feline race, it is alleged that the continuance of the British intellect is dependent upon such conservation—so that a scientific justification of spinsterhood is thus rendered possible.

Sprengel laid down the axiom, already mentioned, that "Nature does not wish any complete flower to be self-fertilised." Darwin in turn improves upon this dictum in his assertion that "Nature abhors perpetual self-fertilisation." That "cross-fertilisation is generally beneficial, and self-fertilisation injurious," is thus a stable result of botanical investigation. This result may not enable us fully to comprehend that "law within the law" which regulates the well-being of the plant-world; but it may at least lead us plainly enough to a nearer fact of life—namely, that there exists in nature an innate tendency to variation and change, and that by furthering the fullest possible development of seeds, as well as by the cross-fertilising of plants, there is being illustrated that tendency to evolve new varieties and species on the existence of which the very idea and possibility of evolution depends. The tendency to produce a more numerous offspring gives naturally a larger number of individuals for the exhibition and operation of the laws of variation. The process of cross-fertilisation itself produces another tendency to variation; and as such variation is the "key-note" of evolution, it is more than interesting to find the conditions of plant-life in such a marked manner contributing to the differentiation of the species.

The whole array of features embraced in a study of flower-fertilisation forms simply a mass of evidence that the production of new races and varieties, and, through these, of new species, is part and parcel of nature's constitution. On any other supposition, the extraordinary array of contrivances favouring cross-fertilisation and the initiation of variations, is meaningless and utterly inexplicable. The facts of fertilisation, like the stages of development, present us with unimpeachable evidence in favour of the evolution of new races by the modification of the old. Even if a fact here or a detail there may seem to weigh against the theory of development, it must be borne in mind, firstly, that defects and gaps in our knowledge are still realities of biological science; and, secondly, that the general—and in this case the immensely overwhelming—probability of nature's and life's methods testifies to evolution as the true way of creation. Mr. Darwin succinctly enough says, that his experiments on intercrossing show that "with animals and plants a cross between different varieties, or between individuals of the same variety but of another strain, give vigour and fertility to the offspring; and, on the other hand, that *close* interbreeding diminishes vigour and fertility." And he also adds that such facts "alone incline me to believe that it is a general law of nature that no organic being fertilises itself for a perpetuity of generations; but that a cross with another individual is occasionally —perhaps at long intervals of time—indispensable." Remarking the strange feature of the stamens and pistil of most flowers being placed closed together, "as if for the very purpose of self-fertilisation," and yet being "mutually useless to each other," Mr. Darwin says, "How simply are these facts explained on the view of an occasional cross with a distinct individual being advantageous or indispensable!" Thus, from the common ground that cross-fertilisation effects the greatest good in nature—namely, the efficient increase of the race—we may find many roads and ways for the recognition of further effects of such action in favouring the operation of the conditions that increase the species by variation and modification. The full bearing of the subject may not be completely investigated for years to come. Sufficient, however, is our present recognition of the fact that in the work of flower-fertilisation lie the beginnings of those activities and processes which herald now, as of yore, not merely the increase, but the variation of species and the evolution of new forms of plants.

Certain matters bearing the same relation to our present subject that the inevitable moral bears to the fable—albeit that they may perchance be regarded as of somewhat superfluous nature—may fitly be touched upon in closing this paper. Our notions of special ends, aims, and contrivances in nature may in one way be enlarged by the considerations which the phenomena of flower-fertilisation present to notice. Under the operation of laws and conditions most of which are as yet beyond our ken, we see insect acting upon flower, and flower in turn reacting upon insect, until the interdependence in some cases proceeds so far that the extinction of the insect means the disappearance of the flower. But, whilst viewing the beauty of form and hue exhibited in the plant-world as wrought out by laws of development, and as accessory, or even primary, conditions in the evolution of living beings, the new and higher aspects of the subject bid us regard floral beauty as subserving other and higher uses than those commonly assigned to it, namely, of ministering to the often dull and inappreciative senses of man. We may detect a higher purpose in plant life than is included in the yet too common idea that man's delight and human interests exclusively determine and rule—through what some are pleased to call "the beneficence of providence"—the concerns of nature at large. The utilitarian cry of "use" and "no use" is by no means extinct, even in these latter days; and the consideration of the ways and means involved in the fertilisation of flowers must devolve a strong argument against the homocentric idea that the beautiful in nature exists solely for the behalf of man. Darwin says, "Such doctrines, if true, would be absolutely fatal to my theory." But there is little fear that the hypothesis in question can suffer from arguments familiar in days when natural theology was strained and wrested to its destruction. A truer and a higher use for the beauty of plants and of animals as well is found in the special advantages which such beauty confers upon the race. In the animal, beauty appears as an aid to the propagation of the species, as it is in the plant; and it is by the action of insects that the beauty of flowers has been extended and developed. The beauty of the blossom is in truth due to the visitations of the insect races which in the past have selected its petals as a feeding-ground, and which have strengthened and increased the flower race, thus favoured by a true "natural selection," in the universal struggle for existence. The higher ideas of nature thus implanted, form no mean fruits of a study of the polity of primroses and other common flowers. Such studies correct the idea that this world is simply a huge workshop, filled with specially contrived mechanical appliances for man's use and benefit, or a gaudy saloon decked out with beauty for the indulgence of his senses. Those who hold such views may not complain if their belief be logically extended to include the theory that fur-seals were specially created to afford us seal-skin jackets, and humming-birds designed to trim the hats of fair wearers in the fleeting fashion of the hour. So that, if no greater excellence be traceable in the theory of evolution than is involved in the correction of false notions of the aims and ends of nature, those who pursue science-studies even to this extent will reap a rich harvest of rational ideas concerning the true ordering of this universe, especially within the domain of life itself.

XV.

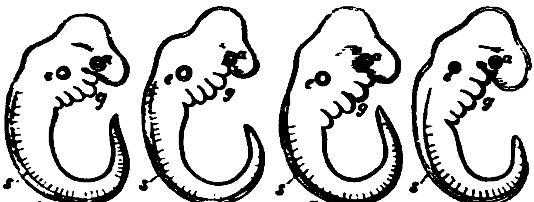
THE EVIDENCE FROM DEGENERATION.

It cannot be gainsaid that a survey of the fields of life around us impresses one with the idea that the general tendencies of living nature gravitate towards progression and improvement, and are modelled on lines which, as Von Baër long ago remarked, lead from the general or simple towards the definite, special and complex. This much is admitted on all hands, and the ordinary courses of life substantiate the aphorism that progress from low grades and humble ways is the law of the organic universe that hems us in on every side, and of which, indeed, we ourselves form part. The growth of plant-life, which runs concurrently with the changing seasons of the year, impresses this fact upon us, and the history of animal development but repeats the tale. In the passage from seed to seed-leaf, from seed-leaf to stem and leaves, from simple leaves to flower, and from flower to fruit, there is exhibited a natural progress in plant existence, which testifies eloquently enough, by analogy at least, to the existence of like tendencies in all other forms of life. Similarly, in the animal hosts, progressive change is seen to convert that which is literally at first "without form and void" into the definite structure of the organism. A minute speck of protoplasm on the surface of the egg —a speck that is indistinguishable, in so far as its matter is concerned, from the *materies* of the animalcule of the pool—is the germ of the bird of the future. Day by day the forces and powers of development weave the protoplasm into cells, and the cells, in turn, into bone and muscle, sinew and nerve, heart and brain. In due season the form of the higher vertebrate is evolved, and progressive change is once more illustrated before the waiting eyes of life-science. But the full meaning of most of the problems which life-science presents to view is hardly gained by a merely cursory inspection of what may be called the normal side of things. The by-paths of development—more frequently, perhaps, than its beaten tracks—reveal guiding clues and traces of the manner in which the progress in question has come to pass. So, also, the side avenues of biology open up new phases of, it may be, the main question at issue, and may reveal, as in the present instance, an interesting reverse to the aspects we at first deem of sole and paramount importance. For example, a casual study of the facts of animal development is well calculated to show that life is not all progress, and that it includes retrogression as well as advance. Physiological history can readily be proved to tend in many cases towards backsliding, instead of reaching forwards and upwards to higher levels. This latter tendency, beginning now to be better recognised in biology than of late years, can readily be shown to exercise no unimportant influence on the fortunes of animals and plants. In truth, life at large must now be regarded as existing between two great tendencies—the one progressive and advancing, the other retrogressive and degenerating. Such a view of matters may serve to explain many things in living histories which have hitherto been regarded as somewhat occult and difficult of solution; whilst we may likewise discover that the coexistence of progress and retrogression is a fact perfectly compatible with the lucid opinions and teachings concerning the origin of living things which we owe to the genius of Darwin and his disciples.

A fundamental axiom of modern biology declares that in the development of a living being we may discern a panoramic unfolding, more or less complete, of its descent. "Development repeats descent" is an aphorism which, as we have seen, cultured biology has everywhere writ large over its portals. Rejecting this view of development and its teachings, the phases through which animals and plants pass in the course of their progress from the germ to the adult stage present themselves to view as simply meaningless facts and useless freaks and vagaries of nature. Accepting the idea—favoured, one may add, by every circumstance of life-science—much that was before wholly inexplicable becomes plain and readily understood. And the view that a living being's development is really a quick and often abbreviated summary of its evolution and descent, both receives support from and gives countenance to the general conclusion

FIG. 241.—DEVELOPMENT OF FROG.

that life's forces tend as a rule towards progress, but likewise exhibit retrogression and degeneration. If a living being is found to begin its history, as all animals and plants commence their existence, as a speck of living jelly, comparable to the adult animalcule of the pool, it is a fair and logical inference that the organisms in question have descended from lowly beings, whose simplicity of structure is repeated in the primitive nature of the germ. If, to quote another illustration, the placid frog of to-day, after passing through its merely protoplasmic stage, appears before us in the likeness of a gill-breathing fish (Fig. 241), the assumption is plain and warrantable that the frog race has descended from some primitive fish stock, whose likeness is reproduced with greater or less exactness in the tadpoles of the ditches. Or if, to cite yet another example, man and his neighbour quadrupeds (Fig. 242), birds, and reptiles, which never breathe by gills at any period of their



A B C D

PIG. CALF. RABBIT. MAN.

FIG. 242.—EMBRYO-VERTEBRATES.

existence, are found in an early stage of development to possess "gill-arches" (*g*), such as we naturally expect to see, and such as we find in the fishes themselves, the deduction that these higher animals are descended from gill-bearing or aquatic ancestors seems to admit of no reasonable denial. On any other theory, the existence of gill-arches in the young of an animal which never possesses gills is to be viewed as an inexplicable freak of nature—a dictum which, it is needless to remark, belongs to an era one might well term prescientific, in comparison with the "sweetness and light" of these latter days.

Hanging very closely on the aphorism respecting development and its meaning, is another biological axiom, well-nigh as important as the former. If development teaches that life has been and still is progressive in its ways, and that the simpler stages in an animal's history represent the conditions of its earliest ancestors, it is a no less stable proposition that at all stages of their growth living beings are subject to the action of outward and inward forces. Every living organism lives under the sway and dominance of forces acting upon it from without, and which it is enabled to modify and to utilise by its own inherent capabilities of action. It is, in fact, the old problem of the living being and its surroundings applied to the newer conceptions of life and nature which modern biology has revealed. The living thing is not a stable unit in its universe, however wide or narrow that sphere may be. On the contrary, it exists in a condition of continual war, if one may so put it, between its own innate powers of life and action, of living and being, and the physical powers and conditions outside. This much is now accepted by all scientists. Differences of opinion certainly exist as to the share which the internal constitution of the living being plays in the drama of life and progress. It seems, however, most reasonable to conclude that two parties exist to this, as to every other bargain; and regarding the

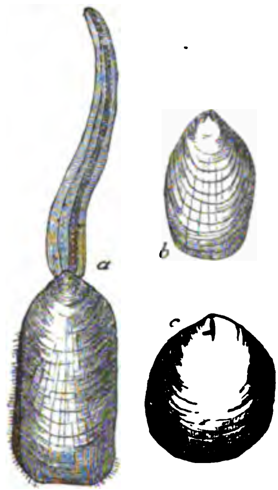


FIG. 243.—BRACHIOPODS.

FIG. 244.—KING-CRAB.

animal or plant as plastic in its nature, we may assume such plasticity to be modified on the one hand by outside forces, and on the other by internal actions proper to the organism as a living thing. Examples of such tendencies of life are freely scattered everywhere in nature's domain. For instance, we know of many organisms which have continued from the remotest ages to the present time, without manifest change of form or life, and which appear before us to-day, the living counterparts of their fossilised representatives of the Chalk or it may be of Silurian or Cambrian times. The lampshells (*Terebratula*) of the Chalk exist in our own seas with well-nigh inappreciable differences. The *Lingula* or *Lingulella* (Fig. 243, *a*), another genus of these animals, has persisted from the Cambrian age (*b*, *c*) to our own times, presenting little or no change for the attention of the geological chronicler. The curious king-crabs or *Limuli* (Fig. 244) of the West Indies are likewise presented to our view, with little or no variation, from very early ages of cosmical history; and of the pearly nautilus (Fig. 247)—now remaining as the only existing four-gilled and externally shelled cuttlefish—the same remark holds good. The fishes, likewise, are not without their parallel instances of lack of change and alteration throughout long ages of time. The well-known case of the genus *Beryx* presents us with a fish of high organisation, found living in the Atlantic and Pacific Oceans, and which possesses fossil representatives and facsimiles in the chalk (Fig. 245). From the latter period to the present day, the genus *Beryx* has therefore undergone little modification or change. The same remark certainly holds good of many of those huge "dragons

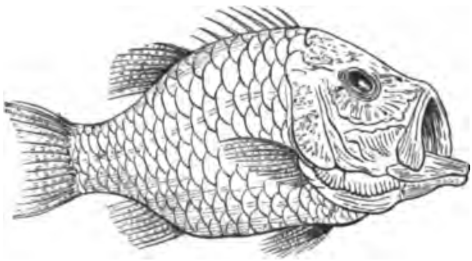


FIG. 245.—BERYX.

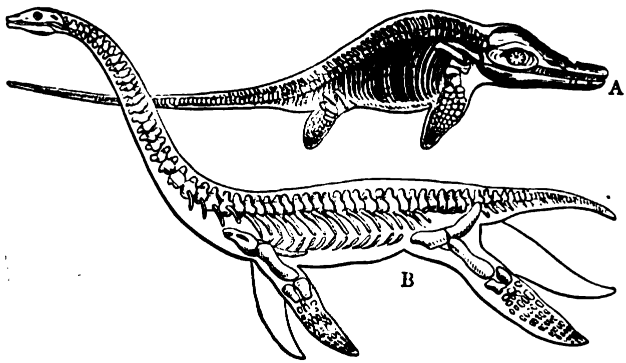


FIG. 246.—ICHTHYOSAURUS (A) AND PLESIOSAURUS (B).

of the prime" (Fig. 246), which revelled in the seas of the trias, oolite, and chalk epochs—developed in immense numbers in these eras of earth's history, but disappearing for ever from the lists of living things at the close of the cretaceous age, and exhibiting little or no change during their relatively brief history.

Such cases of stability amidst conditions which might well have favoured change, and which saw copious modification and progression in other groups of animals, might at first sight be regarded as presenting a serious obstacle to the doctrine of progressive development on which the whole theory of evolution depends. As such an obstacle, the series of facts in question was long regarded. In this light these facts are sometimes even now advanced, but only by those who imperfectly appreciate and only partially understand what the doctrine of evolution teaches and what its leading idea includes. Even Cuvier himself, when advancing the case of the apparently unchanged mummies of Egyptian animals against Lamarck's doctrine of descent, failed—possibly through the imperfectly discussed stage in which the whole question rested in his day—to understand that the very facts of preservation revealed in the monuments of Egypt testified to the

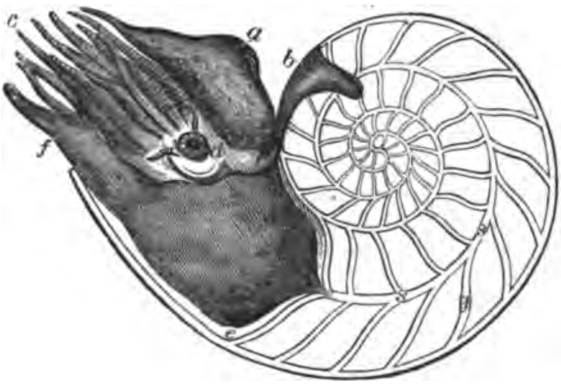


FIG. 247.—PEARLY NAUTILUS.

absence of those physical changes which could alone have affected the animals of the Nile land. But the fuller consideration of that theory of nature which credits progressive change as the usual way of life, shows us that it is no part of evolution to maintain either that living beings must needs undergo continual change, or that they must change and modify at the same rate. On the contrary, Mr. Darwin, in his classic work, maintains exactly the opposite proposition. There are, in fact, two great factors at work in living nature—a tendency to vary and change, and the influence of environments or surroundings. Given the first tendency, which is not at all a matter of dispute, the influence of the second is plainly enough discernible in bringing to the front either the original, primitive, or, as it might be named, the parent form, or the varying forms which are produced by modification of the parent. As it has well been put : "Granting the existence of the tendency to the production of variations, then, whether the variations which are produced shall survive and supplant the parent, or whether the parent form shall survive and supplant the variations, is a matter which depends entirely on those conditions which give rise to the struggle for existence. If the surrounding conditions are such that the parent form is more competent to deal with them and flourish in them than the derived forms, then in the struggle for existence the parent form will maintain itself, and the derived forms will be exterminated. But if, on the contrary, the conditions are such as to be more favourable to a derived than to the parent form, the parent form will be extirpated, and the derived form will take its place. In the first case, there will be no progression, no change of structure, through any imaginable series of ages; in the second place, there will be modification and change of form." To the same end Darwin himself leads us. In one or two very pregnant passages, the author of the "Theory of Natural Selection" very plainly indicates why progression should not be universal, and why certain beings remain lowly organised whilst others attain to the summit and pinnacle of their respective organisations. "How is it," says Darwin, "that throughout the world a multitude of the lowest forms still exist? and how is it that in each great class some forms are far more highly developed than others? Why have not the more highly developed forms everywhere supplanted and exterminated the lower?" Answering his own queries, Darwin says that natural selection by no means includes "progressive development—it only takes advantage," he remarks, "of such variations as arise and are beneficial to each creature under its complex relations of life. And it may be asked, what advantage, as far as we can see, would it be to an infusorian animalcule—to an intestinal worm—or even to an earthworm, to be highly organised? If it were no advantage, these forms would be left, by natural selection, unimproved or but little improved, and

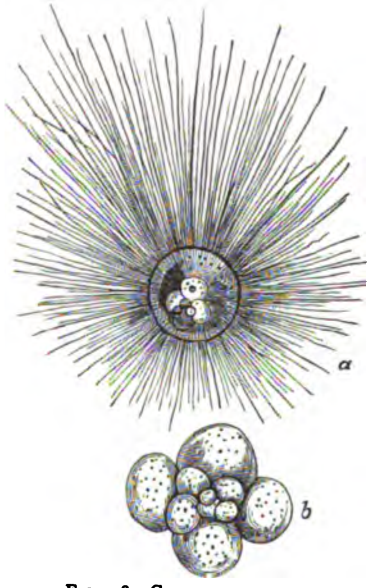


FIG. 248.—GLOBIGERINA, ETC.

might remain for ages in their present lowly condition. And geology tells us that some of the lowest forms, as the foraminifera (Fig. 248), infusoria, and rhizopods, have remained for an enormous period in nearly their present state. But," adds Darwin, with a characteristically impartial view of matters, "to suppose that most of the many now existing low forms have not in the least advanced since the first dawn of life would be extremely rash; for every naturalist who has dissected some of the beings now ranked as very low in the scale must have been struck with their really wondrous and beautiful organisation."

Thus one of the plainest facts of natural history, namely, that in even one group or class of animals we find forms of exceedingly low structure included along with animals of high organisation—the apparently diverse bodies being really modelled on the one and the same type—is explained by the consideration that with different conditions, or with varied conditions acting differently upon unlike constitutions, we expect to find extreme differences in the rank to which the members of a class may attain. In the class of fishes we find the worm-like clear-bodied lancelet of an inch long, associated with the ferocious shark, the active dogfish, or the agile food-fishes of our table. But, as Darwin remarks, the shark would not tend to supplant the lancelet, their spheres and their conditions of existence being of diverse nature. The same remark applies to many other classes of living beings. So that lowly beings still live as such amongst us, and preserve the primitive simplicity of their race, firstly, because the conditions of life and their limited numbers may not have induced any great competition or struggle for existence. On the "let well alone" principle, we may understand why some animals, such as the lancelet itself, have lagged behind in the race after progress. Then, secondly, as Darwin remarks, favourable variations, by way of beginning the work of progress, may never have appeared—a result due, probably, as much to hidden causes within the living being as to outside conditions. We may not fail to note, lastly, that the simpler and more uniform these latter conditions are—as represented in the abysses of the ocean, for example—the less incentive is there for the progress and evolution of the races which dwell in their midst.

This somewhat lengthy introduction to the subject of degeneration and its results, is in its way necessary for the full appreciation of the fashion in which degeneration relates itself to the other conditions of life. From the preceding reflections it becomes clear that three possibilities of life await each living being. Either it remains primitive and unchanged, or it progresses towards a higher type, or, last of all, it backslides and retrogresses. The first condition, that of stability, is, as already noted, perfectly consistent with the doctrine of descent; and the two latter conditions also form part and parcel of that theory. The stable state forces the animal to remain as it now is, or as it has been in all times past; the progressive tendency will make it a more elaborate animal; and the progress of degeneration will, on the other hand, tend to simplify its structure. It requires no thought to perceive that progress is a great fact of nature. The development of every animal and plant shows the possibilities of nature in this direction. But the bearings of degeneration and physiological backsliding are not, perchance, so clearly seen. Hence, to this latter aspect of biology we may now specially direct our attention.

That certain animals degenerate or retrogress in their development before our eyes to-day, is a statement susceptible of ready and familiar illustration. No better illustrations of this statement can be found than those derived from the domain of parasitic existence. When an animal or plant attaches itself partly or wholly to another living being, and becomes more or less dependent upon the latter for support and nourishment, it exhibits, as a rule, retrogression and degeneration. The parasitic "guest" dependent on its "host" for lodging alone, or it may be for both board and lodging, is in a fair way to become degraded in structure, and, as a rule, exhibits degradation of a marked kind, where the association has persisted sufficiently long. Parasitism and servile dependence act very much in structural lower life as analogous instances of mental dependence on others act in ourselves. The destruction of characteristic individuality and the extinction of personality are natural results of that form of association wherein one form becomes absolutely dependent on another for all the conditions of life. A life of mere attachment exhibits similar results, and organs of movement disappear by the law of disuse. A digestive system is a superfluity to an animal which, like a tapeworm (Fig. 249), obtains its food ready-made in the very kitchen, so to speak, of its host. Hence the lack of a digestive apparatus follows the finding of a free commissariat by the parasite. Organs of sense are not necessary for an attached and rooted animal; these latter, therefore, go by the board, and the nervous system itself becomes modified and altered. Degradation, wholesale and complete, is the penalty the parasite has

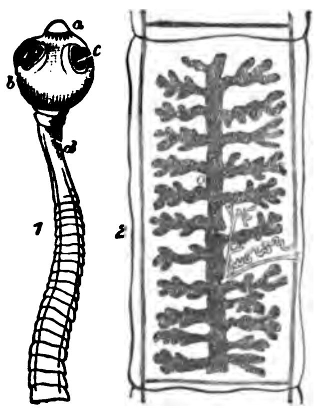


FIG. 249.—COMMON TAPEWORM (*Tænia solium*). 1. The head extremity, magnified, showing hooks (*a*), and suckers (*b*, *c*); *d*, the neck, with immature joints. 2. A joint, largely magnified, showing the branching "ovary," in which the numerous eggs of each joint are matured.

to pay for its free board and lodging; and in this fashion Nature may be said to revenge the host for the pains and troubles wherewith, like the just of old, he may be tormented.

Numerous life-histories testify clearly enough to the correctness

FIG. 250.—SACCULINA.

FIG. 251.—YOUNG SACCULINA.

of the foregoing observations. Take, as an example, the history of *Sacculina* (Fig. 250), which exists as a bag-like growth attached to the bodies of hermit crabs, and sends root-like processes into the liver of its host. No sign of life exists in a sacculina beyond mere pulsation of the sac-like body, into and from which water flows by an aperture. Lay open this sac, and we shall find the animal to be a bag of eggs and nothing more. But trace the development of a single egg, and one may derive therefrom lessons concerning living beings at large, and open out issues which spread and extend far afield from sacculina and its kin. Each egg of the sac-like organism develops into a little active creature, possessing three pairs of legs, generally a single eye, but exhibiting no mouth or digestive system—parasitism having affected the larva as well as the adult. Sooner or later, this larva—known as the *nauplius* (Fig. 251)—will develop a kind of bivalve shell; the two hinder pairs of limbs are cast off and replaced by six pairs of short swimming feet; whilst the front pair of limbs develops to form two elongated organs whereby the young sacculina will shortly attach itself to a crab "host." When the latter event happens the six

FIG. 252.—BARNACLES.

pairs of swimming feet are cast off, the body assumes its sac-like appearance, and the sacculina sinks into its adult stage—a pure example of degradation by habit, use, and wont. So also with certain near neighbours of these crab-parasites, such as the Lerneans, which adhere to the gills of fishes. Beginning life as a three-legged "nauplius," the lernean retrogresses and degenerates to become a mere elongated worm, devoted to the production of eggs, and exhibiting but little advance on the sacculina. There are dozens of low crustaceans which, like sacculina, afford examples of animals which are free and locomotive in the days of their youth, but which, losing eyes, legs, digestive system, and all the ordinary belongings of animal life, "go to the bad," as a natural result of participating in what has been well named "the vicious cycle of parasitism."

Plainly marked as are the foregoing cases, there are yet other familiar crustaceans which, although not parasites, as a rule, nevertheless illustrate animal retrogression in an excellent manner. Such are the sea-acorns (*Balani*), which stud the rocks by thousands at low-water mark, and such are the barnacles (Fig. 252), that adhere to floating timber and the sides of ships. In the development of sea-acorns and barnacles, the first stage is essentially like that of the sacculina. The young barnacle, as our previous studies have shown, is a "nauplius," three-legged, free-swimming, single-eyed, and possessing a mouth and digestive apparatus. In the next stage we again meet with the six pairs of swimming feet seen in sacculina, with the enormously developed front pair of legs serving as "feelers," and with two "magnificent compound eyes," as Darwin describes the organs of vision. The mouth in this second stage, however, is closed, and feeding is therefore impossible. As Darwin remarks, the function of the young barnacles "at this stage is to search out by their well-developed organs of sense and to reach by their active powers of swimming a proper place on which to become attached, and to undergo their final metamorphosis. When this is completed," adds Darwin, "they are fixed for life; their legs are now converted into prehensile organs; they again obtain a well-constructed mouth, but they have no antennæ, and their two eyes are now reconverted into a minute, single, simple eye-spot." A barnacle is thus simply a highly modified crab-like animal which fixes itself by its head to the floating log, and which "kicks its food into its mouth with its feet," to use the simile and description of biological authority. The development of its "shell" and stalk are matters which do not in the least concern its place in the animal series. These latter are local and personal features of the barnacle tribe. For in the "sea-acorns," which pass through an essentially similar development, there is no stalk; and the animal, after its free-swimming stage, simply glues its head, by a kind of marine cement of its own manufacture, to the rock, develops its conical shell, and like the barnacle uses its modified feet as means for exercising the commissariat and nutritive function. It is true that in some respects the adult barnacle may be regarded as lower than the young, and therefore as a degenerate being. Thus, it is lower when eyes, feelers, and movements are taken into account. In other respects the adult may be considered of higher organisation than the larva. These higher traits we may logically enough suppose represent the special advances which adult barnacle life has made on its own account. But, on the whole, degradation and retrogression, if not so fully exemplified as in the sacculina, is still plainly enough illustrated in barnacle history. When we further reflect that even such high crustaceans as prawns and allied forms begin life each as a "nauplius" or under an allied guise, we not only merely discover the common origin of all Crustaceans in some form represented by the "nauplius" of to-day, but we also witness the possibilities of development which have placed shrimps,

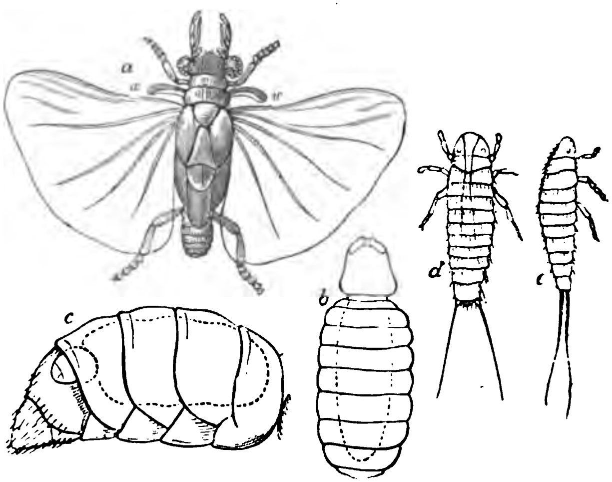


FIG. 253.—STYLOPS.
(Fig. *c* shows the Stylops, in outline, within the body of the bee; and Fig. *b* shows the Stylops removed from the body of its host.)

prawns, &c., in the foremost rank of the class, and which, conversely, have left the barnacles and sacculinas, through the action of degenerative changes, amongst the groundlings of the group.

The assumption of a sedentary life, whether parasitic in nature, like that of sacculina, or whether represented by mere attachment and fixation to some inorganic thing, as in the case of the barnacles, is therefore seen to operate in the direction of producing degeneration of the animal's constitution. The tendency of such habit is towards simplification of structure, and not towards that progressive advance and evolution which, in the case of the higher crustacean races, have evolved from the relatively simple "nauplius" of the past the crabs, lobsters, shrimps, and prawns of to-day.

In groups of the animal series, however, both nearly allied to the crustacean class, and far removed from it in structure, equally interesting and often curious examples of degradation may be found. The class of insects, and the nearly related group (*Arachnida*), including the mites, spiders, and scorpions as its representatives, number in their ranks instances of degraded and degenerate forms. Amongst the insects which are parasitic in habits a notable absence of wings is discernible, and this latter want is seen even in those cases in which one sex alone of a particular insect species assumes the habit in question. An excellent illustration of such a fact, and also of the extreme modification of form which may accompany the degeneracy of highly organised animals, is found in the history of the insects collectively known as Strepsiptera, and of which the genus *Stylops* is the best-known example. The male Stylops (Fig. 253, *a*) is an active insect, possessing a single pair of wings. These wings are the hinder pair; the front pair being represented by a pair of twisted organs (*w*), which illustrate wing-degeneration, possibly through disuse. Both males and females, as they leave the egg, are small, active, six-legged beings (*c*, *d*), which crawl about on the bodies of bees. Carried into the hive, the young stylops behave like the proverbial viper, injuring the community which gives them shelter by boring their way into the bodies of larval or infant bees. Here the young stylops, casting their skin, become, in the larval interior, sluggish, footless grubs. Each possesses a mouth, small jaws, and a digestive system of simple construction. Meanwhile, bee-development progresses; and as the larval bee passes through its chrysalis state with its stylops-lodger contained in its interior, the latter thrusts the front extremity of its body from between two of the hinder body-segments of the bee. Then the male stylops, undergoing development in this position, becomes the winged insect (*a*) and passes into the world. The female stylops (*c*), on the other hand, remain in their places on the bees. They undergo but a slight change of form, persisting as mere sac-like bodies (*c*) without legs or digestive system (*b*), and develop in their interior the eggs from which succeeding generations of stylops will be produced. Such a case of absolute degeneracy is all the more remarkable in view of the facts that it is limited to one sex alone, and that the free-winged males of stylops are as highly organised as most of their neighbour insects.

The class of the spiders (*Arachnida*) offers collective examples of degeneration and retrogression, which show how large numbers of animals may acquire lower characters, contrasting with the higher phases to which other members of their class have attained. The mites and ticks have unquestionably originated from the same root-stock as the spiders and scorpions. The development of the two groups proves this much. But whilst the latter animals have advanced to a high complexity of organisation, the mites and ticks have degenerated into parasitic forms—or at least exemplify beings which, first attaining a respectable rank in their own series, have certainly not advanced upon that rank. Many of the mites, however, exhibit well-marked degeneration. Only on the hypothesis of sweeping retrogression can we account for the singular and anomalous condition in which a certain harmless mite, named *Demodex folliculorum* (Fig. 254), spends its existence. This mite inhabits the sacs or follicles of the human skin at the sides of the nose. It is a minute worm-like animal, possessing eight degenerate rudiments of legs, and a thoroughly rudimentary structure in other respects. Here parasitism has denuded the animal of well-nigh every attribute of its Arachnidan character, and has left it in a condition analogous in many respects to sacculina itself. Of the equally curious *Linguatulina* (Fig. 255) inhabiting the "frontal sinuses" or forehead spaces of dogs, wolves, horses, and sheep, the same remark holds good. The body here is thoroughly worm-like in shape (*b*, *c*), and a digestive and nervous system are to be enumerated among the possessions of the organism. But not even the rudiments of legs are to be perceived, although the mouth bears certain apologies for the appendages proper to that region in the mite and spider class. Yet the young Linguatulina (*a*) exactly resembles the early form of the mites. It possesses two pairs of jointed limbs, and certain style-like organs pertaining to the mouth. There is thus the clearest evidence that Linguatulina is a degraded animal. It is the degenerate descendant of a free living and apparently four-legged—or it may be eight-legged—ancestor; and its further history seems to afford a clue to the causes of its retrogression. For the four-legged larva of Linguatulina escape whilst still within the egg from the nose of the dog or sheep host which has harboured their

FIG. 254. DEMODEX (magnified).

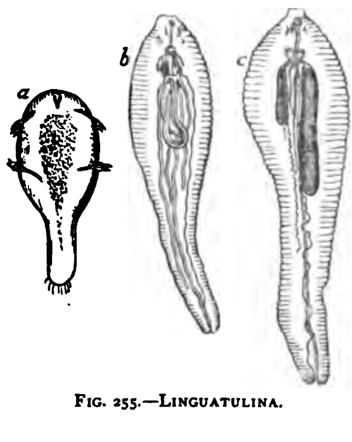


FIG. 255.—LINGUATULINA.

parents. Received, along with food, into the body of the hare or rabbit, the larval being liberates itself. From the rabbit's digestive system it bores its way through the tissues to the liver, thus reminding one strongly of the similar migrations of the embryo-tapeworm. In the liver, further changes ensue. Frequent moultings become the order of the day; and at length they assume a worm-like aspect, and remain thus, still imperfect, until, by transference to the body of dog, wolf, or sheep, and by passage to the frontal sinuses, they acquire perfection of their life-functions. If the history of these beings teaches us anything concerning their past, it points to a free and active state as their original condition, and to the probable acquirement, first, of a lodgment in the digestive system of one animal as a relatively simple parasite, and secondly, of a further modification of habit transferring at once its perfection and completed degradation to the forehead-cavities of a second host.

But the conditions which make for the degeneracy of an animal are, as we have seen in the case of the barnacles, not always associated with a parasitic habit. Mere fixation, as we have observed, secures the disappearance of useless organs, such as organs of motion and sense-organs, which, being possessed by the young form, clearly indicate that the ancestry of the animals in question has at any rate been capable of leading to better things than the descendants represent in their existent persons. The sea-squirts, or ascidians, besides serving as a text for the derivation of vertebrates, and for abnormal ways in the animal chemistry which imitates the plant's work, have been selected as fruitful objects of discussion by those biologists who find in the idea of degeneration an explanation of knotty points in natural history. For the same voice that proclaims the fact that a sea-squirt—which is a mere rooted bag with a double neck (Fig. 256)—begins life as a free-swimming, tadpole-like larva (Fig. 257, 5), tells us in the same breath that there must have been retrogression and degeneration from an active condition to produce the sac-like adult state. The assertion that the youthful sea-squirt, moreover, possesses first a rod-like body—called the *notochord* (Fig. 257, *n*)—only found besides in the young of Vertebrate animals, is also to be taken as implying the superiority of ascidian infancy to sea-squirt maturity. And when it is added that the elderly squirt wants the sense-organs and nervous cord which the larva possesses, it may well be argued that sheer degeneracy of habit and structure can alone account for the sweeping transformations which mark the phases of ascidian life-

FIG. 256.—SEA-SQUIRT.

history. Thus it is matter of sober natural-history fact that a sea-squirt larva, of all invertebrate animals, is the only being that possesses organs and parts proper to the young vertebrate or to the *adult* form of one lower vertebrate in particular. This adult is the little fish known as the lancelet, which, in the relative simplicity of its organisation, makes a nearer approach to the poor (or sea-squirt) relations of the vertebrates than any other fish.

The fact of vertebrate and sea-squirt relationship is worth dwelling upon, because the topic unquestionably presents one with a common point of view, whence a survey of the higher development, evolution, and progress of the vertebrates, and a view of the degeneracy and retrogression of the sea-squirts, may best be obtained. Revelling in the freedom of its early life, the larval sea-squirt—presenting, as already noted, a striking resemblance to the tadpole of the frog, in its backbone, its nerve-system, and its breathing-sac, or modified throat—ultimately settles down. Like the youthful barnacle somewhat, the young sea-squirt attaches itself to a stone or shell by the suckers with which nature has provided its head. Then succeeds the disappearance of the tail, with its backbone and its nerve cord, and the body itself soon assumes the sac-like shape that betokens the mature ascidian character. The outer skin becomes tough and leathery, and develops the *cellulose* which, by biological right, we might expect to find in plants alone. Then succeeds the fuller formation of the gill-sac or breathing chamber, and of its neighbour compartment, which receives the effete water of respiration to be ejected by the second mouth of the sac-like body. The eye of the larva likewise disappears, and all that remains to the adult ascidian is a nerve mass, called by courtesy the "brain," and which serves to regulate the few acts that mark the placid and rooted existence of the race.

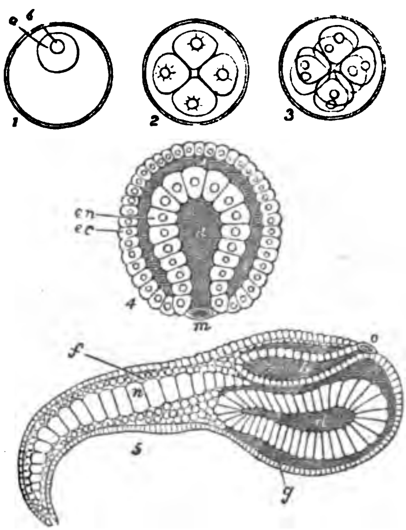


FIG. 257.—DEVELOPMENT OF SEA-SQUIRT.

Attention has been recently directed in a special manner to the resemblance which exists between the eye of the larval sea-squirt and that of vertebrates—a statement to be taken along with that which conversely declares the unlikeness of the ascidian eye to that of all other invertebrate animals. It is matter of fact that the chief parts of the eye of a vertebrate animal grow inwards as developments from the skin, and unite with an outgrowth from the brain. This outgrowth forms the *retina*, or nervous network of the eye, whereon the images of things seen are duly received for transmission to brain and sensorium. Now, in invertebrate animals the retina is formed from the skin-layer. This latter method of growth, it has been remarked, is a perfectly natural one. It was to be expected that, as the retina is to be affected in the discharge of its duty by light rays, it should form on the surface of the body where the light-rays fall. In the vertebrate, and in the sea-squirt larva, the retina, on the contrary, forms away below the skin surface, and grows outwards from the brain. Why is this so? Professor Ray Lankester maintains that because the ascidian larva is perfectly transparent, the light-rays pass through to its brain eye, and thus give rise to sensations of sight. Hence, if the original and primitive vertebrate animal or rootstock were like the larval sea-squirt, as we suppose it to have been, its body would be transparent, and its eye or eyes, situated on its brain, would receive light-rays through its clear body. But as the evolution of the vertebrate race proceeded, the tissues became firmer and denser. By "natural selection"—or, in other words, by the exercise of accommodating power to function—the eyed region of the brain would tend to grow more and more towards the body's surface, to receive the rays of light. As development, therefore, advanced, the mode of growth of the vertebrate eye would be adapted to the exigencies of its new surroundings. Thus, to-day, the vertebrate eye grows from without inwards, because light-rays strike naturally on the outer surface of the body. But it likewise grows from within outwards as well, because of the ancestral and hereditary tendencies which cause it to repeat, in the individual growth, the passage to the surface it had to make in the evolution of the race. If one might add a suggestion to such an explanation, it would consist in an endeavour to account for that affinity between brain and outer surface of body which we see to exist. Why the brain should grow outwards, as it does in eye, ear, and nose likewise, to connect with the body's surface, and so to form organs of sense, is plain enough. We must bear in mind that the brain itself is formed from the outer layer or *epiblast* of the larva, and from the same layer which develops into the skin. Brain and skin, to begin with, arise from the same layer. Hence, before even the matter of eyes falls to be considered, the affinity of the skin layer and the nervous system is a fact worth noting. It is this truest of relationships which may reasonably enough explain, not merely why the sense organs arise from the skin surface, but also why the brain grows outwards to meet with the structure to which it is so near akin.

Degeneration of a very pronounced kind, thus accounts for the peculiarities of sea-squirt structure to-day. The case of ascidian retrogression is likewise the more interesting, seeing that its reverse side is that of progressive evolution and development of the highest forms of life the existing world knows. It is therefore important to note in passing that the possibilities of development may include degeneration of a very marked type, along with progressive evolution of equally pronounced kind. The category of life's extension includes, in fact, many possibilities which at first sight might appear of most unlikely kind; and amongst these possibilities, that of extreme degeneration is by no means the least notable as an element in inducing the material variety of life we behold in the animal and plant worlds of to-day. The list of causes which lead to the degeneration of living beings includes, however, other fashions of producing retrogression than by fixation and parasitic habits, and operates in different ways upon organisms of varied structure and of different social or biological rank. Changes in food and feeding may thus accomplish degeneration and induce physiological backsliding of the most typical description. It is a familiar fact that the animal organism is of relatively higher nature than the plant, seeing that the animal frame can, as a rule, feed upon and build up its tissues from organic or living matter only. Animals, in other words, demand the substance of other animals or of plants, or of both combined, as a necessity of their commissariat arrangements. Plants, on the other hand, are specially constructive and elaborative in their feeding. They build up from the non-living matters around them—carbonic acid, water, ammonia, and minerals—the tissues of their living bodies. They "transubstantiate" this non-living matter into living tissue; and the verdant tints of spring, the full glory of the summer's blossom, or the mellow ruddiness of autumn's fruits, represents, each in its way, the result at once of the plant's constructive chemistry and of the elaboration into living matter of the inorganic materials of air and soil around.

The animal frame therefore presents us—amid exceptions to the above rule in both animal and plant series—with relatively greater complexity of organs and tissues than the plant body presents. This statement simply re-echoes what commonplace observation daily demonstrates. Hence, it may be a natural enough inference that whatever causes tend to bring the animal feeding nearer in type to that of the plant will tend to simplify animal structure, and so to produce retrogression and degeneration of the animal type. Many animals are thus known to develop *chlorophyll*, or the green colour we see characteristically in every leaf. Through the combined operation of this green colour—either singly or aided by the leaf protoplasm—and the action of light, plants decompose the carbonic acid of the air, as every schoolboy knows. They then retain the carbon to aid in the formation of starch, and set free the oxygen, which thus returns to the atmosphere, and is welcomed by the animal hosts. The hydra, or common fresh-water polype (Fig. 258), many animalcules, and certain worms of a low type possess this chlorophyll. Like dishonest manufacturers, they seem to have infringed the patent rights of the plant to elaborate this green colour. And it is no longer matter of theory, but ascertained fact, that these green animals are capable, like the plants, of absorbing carbonic acid—usually a fatal gas to the animal constitution—and

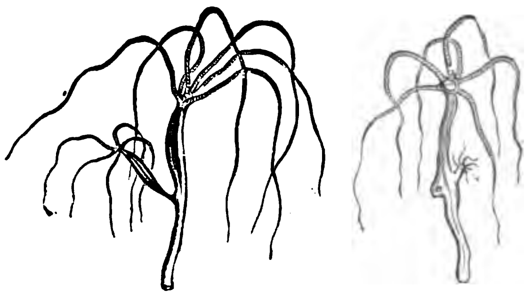


FIG. 258.—HYDRÆ.
(In both figures young hydræ are represented budding from the side of the parent.)

of elaborating starch therefrom like their plant neighbours. Thus a simpler mode of feeding, obviating the necessities of animal existence in the way of digestive apparatus, has apparently led to the simplification of structure. Degeneration has followed in the worms just mentioned, as the result of their imitation and acquirement of vegetative powers of feeding; and it is probable that other alterations in the way of dietary, of less sweeping character than that just mentioned, will affect, in like retrogressive fashion, the animal constitution.

Some of the most curious cases of degeneration known to us illustrate the total disappearance of digestive apparatus even in some beings, in which, as in the stylops already mentioned, one sex becomes retrogressive whilst the other sex remains structurally fully developed. Such a case is illustrated by the males of those remarkable organisms, the *Rotifera*, or "wheel animalcules" (Fig. 259). These minute creatures, inhabiting our fresh waters, may be desiccated and dried, and revived, on the application of moisture, many times in succession. But in their ordinary existence, and in the details of their structure, the "wheel animalcules" present details equally interesting with their exhibition of "potential vitality." The female animalcules possess a complete digestive system, a set of water vessels, a nervous ganglion, and other belongings; but their partners are decidedly inferior creatures, since their digestive system becomes totally abortive; whilst in size, the males are likewise far excelled by the lady rotifers. How this degeneration and disappearance of digestive apparatus and the inferiority of size have been produced in the male rotifers, may be a matter regarding which difference of opinion will certainly exist in biological minds. The fact that retrogression is here illustrated, however, cannot be questioned. It may also be added that, in all probability, the extreme development of the function of perpetuating the species, and the extraordinary fertility of production witnessed in these animalcules, may satisfactorily account for the abrogation of digestion in favour of reproduction. Thus, to the other causes of degeneration in animal life and structure, we may append that which takes origin from the extreme or excessive development of one function over another. Physiological development in one direction, overstepping the natural and ordinary limits, runs concurrently with destruction of life's equilibrium, and naturally tends to produce degeneration and simplification of other organs and of other duties of life.

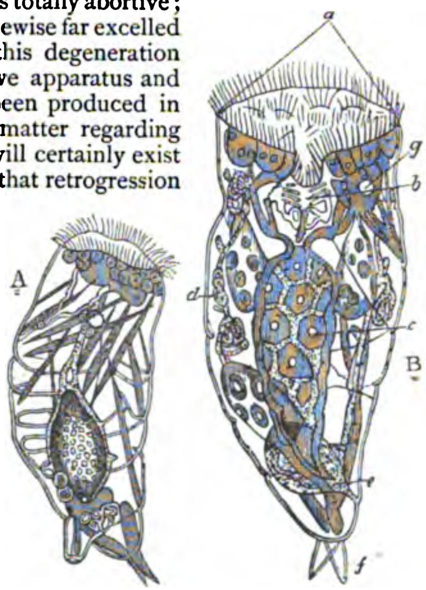


FIG. 259.—ROTIFERA.

How far the theory of degeneration we have thus briefly discussed may be applied in explanation of the peculiarities of animal structure, remains as a task for the future of biology to satisfactorily determine. Possibly the corrections which the future of every hypothesis carries with it may be many and sweeping. The deductions and inferences we extract from a study of degeneration to-day may perchance be falsified by the higher and newer views of the to-morrow of biological science. But enough has been said to show that, even in a cursory review of the doctrine of degeneration and retrogression, many phases of living histories become theoretically plain; and it argues hopefully for the correctness and value of the doctrine before us that it has, so far as it has been logically pursued, fitted compactly and harmoniously enough with ascertained facts and with received views of the origin of animals and plants. That higher forms of life than the sea-squirt and insect race are by no means exempt from the influence of retrogressive change, is an observation worth noting at the close of our researches. We know, for instance, of lowly structures in shell-fish life appearing in the midst of highly organised frames. A mussel, a cockle, or an oyster, whose early development, as we have seen, runs in parallel lines to that of the snail and whelk-class, is nevertheless esteemed less highly organised than the latter. The mussel or oyster-tribe possess no head. The snails and their allies, as every one knows, not merely exhibit a well-developed head, but have that extremity provided with eyes, tentacles or feelers, and other addenda of the front region of the animal body. Hence it is more than probable that the mussel, headless and enclosed in its shell, and possessing relatively little interest in the affairs of the outer world, is an example of a degenerate type of molluscs. The mussels and their relations stand, in fact, at the opposite extreme of development in this respect from those well-known molluscs the cuttlefishes. In these creatures, the tendency to head-development—or what Professor Dana calls "cephalisation"—reaches its maximum, as any one may readily enough suppose on looking at an octopus or squid, with its great head, its enormous eyes, and its nerves massed together to form a brain enclosed in a kind of skull. Even as compared with the earlier cuttlefishes—whose shells, under the name of ammonites and the like, we find fossilised in large numbers—the squids and cuttles of to-day present, in the extreme development of head, a noteworthy advance.

Thus, whilst the one Molluscan tribe of mussels and their neighbours has degenerated and gone to its own lowly place in the series, other groups starting on an equal footing have advanced, and, through progressive evolution, have produced those higher manifestations of molluscan life that teem in the seas of to-day. Even amongst the Vertebrate animals we meet with examples of degenerative tendency which are not so easily explicable as the foregoing illustrations. In most snakes only one lung is fully developed as a rule, the companion organ being rudimentary and degenerate. In birds, the egg-producing organs are similarly developed on one side only. How degeneration should be thus partial, and affect one-half of an animal's frame, so to speak, is very hard to discover. External conditions of life and the influences of surroundings could apparently possess little effect in inducing such an unsymmetrical retrogression of parts. Most probably we shall find the solution of such conditions to exist within the operation of some deep-seated law of the living constitution, and in the effects of that law in moulding or even contorting the animal frame.

It constitutes one of the chief glories of biological science, as pursued amongst us to-day, that its studies are of far-reaching order, and lead, as the results of their natural extension, to the consideration of fields of thought often widely removed from the original topic which interests the reader. The present subject of degenerative changes, regarded as part and parcel of the living constitution, can readily be shown to possess applications far removed from zoology and botany, and extending into the most intimate spheres and phases of human history itself. Degenerative change in human tissues is medically symptomatic of very many of the ills to which flesh is heir. Tissues and organs degenerate in individual animals, as animal frames retrogress in their entirety. Cells retrograde and fibres degenerate in our bodies, just as the sea-squirt's frame exhibits, as a whole, a universal physiological backsliding. Nor may many of our diseases alone be esteemed mere examples of degeneration affecting our tissues. The termination and decline of life itself, and the age that really "melts in unperceived decay," are in reality examples of natural degeneration also. The decline of existence is largely a retrogression of structure. There can be no such thing as a really "green old age," any more than we can speak of "the sere and yellow" of the autumnal leaf as imitating the verdant nature of the spring blossom. Nay, stranger still is it to discern that the full flush of life's vigour is accompanied by degenerative changes as typical as those which mark life's decline. For every tissue wastes as it works; and cells degenerate, die, and are cast off from every surface and tissue of our frames as the natural result of living and being. "Generally speaking," says a writer in discussing the degeneration of human tissues, "those parts which live most slowly are those of which the duration is the greatest, and in which there is consequently the least frequent change. Of the exuviation of epidermic structures *en masse*—a process altogether comparable to the fall of the leaf—we have striking examples in the entire desquamation of serpents, the moulting of the plumage in birds, and the shedding of the hair in mammalia; and in the shedding of the antlers of the stag we have an example of the exuviation of a highly organised and vascular part, which periodically dies, and which, being external, is cast off entire. 'What means all this,' says Sir James Paget, 'but that these organs have their severally appointed tissues, degenerate, die, are cast away, and in due time are replaced by others, which in their turn are to be developed to perfection, to live their life in the mature state, and to be cast off?'" And, again, the same high authority remarks that "it is, further, probable that no part of the body is exempt from the second source of impairment; that, namely, which consists in the natural death or deterioration of the parts (independent of the death and decay of the whole body) after a certain period of their life. It may be proved, partly by demonstration, and partly by analogy, that each integral or elemental part of the body is formed for a certain natural period of existence in the ordinary conditions of active life, at the end of which period, if not previously destroyed by outward force or exercise, it degenerates and is absorbed, or dies and is cast out; needing, in either case, to be replaced for the maintenance of health." To these weighty words we may lastly add the opinion of Dr. Carpenter, who remarks that, "when the adult type has once been completely attained, every subsequent change is one rather of degeneration than of development, of retrogression rather than of advance."

Degeneration is thus an invariable concomitant of life. So far from being in any way an abnormal phase of living action, it is seen to be as natural a process for living beings to retrogress— wholly, as we have seen in some cases, or partly in others—as it is for them to develop and advance. And what is thus undoubtedly true of the individual man or other animal, is no less so of the race. "Buried civilisations" are by no means unknown; extinct culture is an archæological fact; the decline and fall of nations is matter of history. May not these things be likewise explained as a part of that wide theory of life which regards even the highest interests of man as lying within the operation and sway of causes which mould his physical organisation? If this notion be accepted, then is the idea of degeneration as a normal phase of life rendered still more feasible and plain. Reaching to the individual and to the species as well; extending and including in its scope the lowly organised as well as the higher being; affecting one group or class lightly, and influencing another well-nigh to the complete exclusion of progress,—we find degeneration and retrogression to be numbered among the stern realities of existence. And no less clearly and forcibly may we trace the truly natural place of degeneration in our own physical history: since, as physiology teaches and daily experience declares, not an action is wrought or a thought conceived without the presence of change and decay of tissue—a process this which, limited in early life by progressive growth and by development, at last comes in our latter days to assume the reins of government, and in time to dissipate our energy and substance into the nothingness of physical and corporate extinction.

The philosophy of biology, however, may, in conclusion, be found to point out to us that the subject of degeneration, whilst treating of a powerful factor in modifying the living form, yet possesses a favourable aspect in relation to progress and evolution. High authority in matters biological may be found for the statement that degeneration is really a result of progress, that it is dependent on high development, and that, whilst it simplifies the living being, "it produces the same effect as differentiation, for it leads to variety in form." Thus there is a kind of evolution and progress inseparable even from degeneration itself. For the retrogression may in itself lead to variety and change, and in due time such variety may be the starting-point of new and higher developments. So, likewise, we are reminded that reduction and degeneration of some parts may proceed contemporaneously with the higher development of others, with the total result of perfecting the organism, and of evolving a higher type of structure. The degeneration of a frog's tail is in reality a feature of its higher type as compared with its tailed friends the newts and salamanders. The disappearance and reduction of the tail which the young crab possesses, is a chief reason why we esteem the crab, whose body is all head and chest, a higher animal than the lobster or prawn with head, chest, and tail complete. The degeneration of the "outside" gills of the Alpine salamander's young, which never have access to water, is not a mark of inferiority but of superiority; it is, in reality, the casting-off of the old or larval and aquatic characters and the putting on of the new and higher features of the land animal. Even the degeneration of human structures—the modification of the tail which early human existence exhibits, and of muscular structures well developed in lower life—are no proofs of inferiority, but are evidences of superiority in ourselves. Thus, even in the great work of evolving higher races out of the lower, to degeneration much is owing for its aid in repressing larval characters and the structures which belong to lower existences. Whilst progressive evolution develops the great tree of life, extends each branch, clothes it with verdure, and expands each blossom, it is degeneration which lops the worn and aged stems, prunes the weakly foliage, trims the budding growths, and so directs and moulds the outlines of the organic whole. It is to evolution and progress that the world of life largely owes its forward march. But hardly less is the debt of gratitude due by the living hosts to degenerative change and retrogression which, though stern and ofttimes cruel in their ways, nevertheless mark wisely and well the pathways of life, and prevent the useless and weak from cumbering the ground.

XVI.

GEOLOGY AND EVOLUTION.

ALLUSION has frequently been made in preceding chapters to the fact that the deductions of geology and the theory of evolution possess many relations in common. The relationship in question has been demonstrated more than once in the course of our inquiries into the evidence which living nature presents of the truth of the development theory. For example, the case for "missing links," and for the substantiation or denial of the connected series of beings which evolution postulates, was seen to be one which must stand or fall accordingly as the geological evidence revealed the existence of "links" or not. If the history of the fossil contents of the rock-formations could be shown to include no examples whatever of the "transitional forms" between species which the evolutionist demands, it is clear that the validity of his special conception of the order of nature would thereby be seriously impugned. The least cultured critic of the theory of descent would naturally turn to the geological evidence in search of confirmation or refutation of the views advanced by the followers of Mr. Darwin. Hence, in the early days of evolution, when the theory was in its infancy, the relations of geology to this conception of nature were foreseen to be of a kind demanding the most careful attention from both promulgators and opponents of the hypothesis of descent. In this view of matters, the chapters on the "Origin of Species," dealing with the "Imperfections of the Geological Record," and with the "Geological Succession of Organic Beings," have always been regarded with special interest alike by evolutionists and their opponents. Mr. Darwin had undoubtedly felt the high importance of the geological side of the great question he had propounded before the world of thought. The two chapters just mentioned, bear plain evidence of the pains-taking care with which the venerable author of the classic work marshalled the evidence at hand, and with which also he reviewed the conclusions to which that evidence seemed to point. A perusal of the chapters in question will serve to show how consistently the facts of geology may be placed beside those revealed by the study of the life that exists to-day, and how the facts of life's past development often support, whilst they never negative, the ideas on which the evolutionist bases his belief.

The aspects which the geological evidence offers for the attention of the evolutionist are manifold in number and variety. Our study of "missing links" has already shown us that one special phase of geological inquiry relates to the existence in the fossil record of those forms which may be described as intermediate in nature between existing species. If we suppose that no such forms had been known to exist, we can conceive that whilst their absence would not absolutely have negatived the theory of evolution, the want of such evidence would have decidedly weakened the evolutionist's case. The fulness with which the gaps have been supplied with even a relatively limited search in geological directions, has more than satisfied the evolutionist of the correctness of his deductions respecting the existence of the transitional forms he would expect the life of past æons to have exhibited. A second phase of geological inquiry in relation to the theory of descent is found in the question of past time and its duration. The objection has naturally been urged, that, if "natural selection" has operated in the past by the production of minute variations, acting through periods of immense antiquity, the drafts which the evolutionist is compelled to make on the bank of time are so great that collapse of the theory is the result. Physicists of the highest eminence have formulated opinions, based on apparently stable data, regarding the age of our planet. It has accordingly been urged that, assuming the most extended antiquity which such opinions allow, there yet remains a deficit in the age of the earth, compared with the demands or with the expectations of the evolutionist. But to all such speculations and considerations there remains one sufficient answer. So long as we are comparatively ignorant of the exact factors to which the work of evolution is due, it is idle to speculate on the time required for the change and modification of species. That specific change may have occasionally been more rapid in past ages than at present, is an idea for which there is considerable justification to be found in the history of the living beings we are able to study. Again, with imperfect knowledge of the progress and succession of climatal and other changes in the past, and with but shadowy ideas regarding the possibilities of biological change to-day, we have ample reason to regard the relations of time past to evolution, as by no means so simple as certain opinions would appear to indicate. The evidence of geology itself, whilst rejecting the ancient ideas of "catastrophism" and of sudden, cataclysmal changes, nevertheless must be held as proving that cosmical and physical actions have not always presented the phases we see exemplified before our eyes to-day. In a word, until we have at hand fuller evidence regarding the manifest interaction between cosmical alteration and biological change—between physical revolutions and their effect upon the life of our globe—all speculations concerning the duration of time past in its relation to evolution must be held as purely tentative and provisional. The case for evolution, as indicated in our previous studies, is so overwhelmingly strong when we regard the evidence from biology alone, that the evolutionist may well be pardoned if he is inclined to turn a deaf ear to any arguments against his theory which are derived from data so manifestly imperfect in their details as those on which speculations concerning past time and life-development are based.

As bearing in the most intimate manner on this very question of time in relation to evolution, it may be interesting to point out that vast periods of unrepresented time must be allowed for in all considerations connected with the past history of the earth. If we tabulate the various fossil-bearing rock-formations in the order in which they occur in nature, the following table will represent their succession :

KAINOZOIC PERIOD ("Recent Life").	Post Tertiary and Recent. Pliocene. Miocene. Eocene.
MESOZOIC PERIOD ("Middle Life").	Cretaceous or Chalk. Oolite or Jurassic. Trias.
PALÆOZOIC PERIOD ("Ancient Life").	Permian. Carboniferous. Devonian, or Old Red Sandstone. Silurian. Cambrian (and Huronian). Laurentian.

This table shows us that the fossil-bearing rocks are arranged in a very definite order and succession; the lowest, and therefore the oldest, series being the "Palæozoic" rocks, which in turn possess the Laurentian group as their most ancient formations, and the Permian rocks as their newest. Above these, again, lie the "Mesozoic" rocks, with the Trias, lying above the Permian, as their oldest, and the Chalk, reposing in turn on the Oolite, as their youngest beds respectively. The "Kainozoic" rocks form the last and most recent series of all. They lie upon the Chalk, their oldest strata being those named the Eocene, and their youngest formations the soils and gravels of to-day. It is needless to remark that this tabular order is never anywhere seen in its entirety. Geological revolution disturbing the strata, has produced many and serious breaks in their continuity. But such gaps do not affect the order of their succession tabulated by the geologist; that is to say, the Permian, for example, wherever found, must overlie the Coal, as the latter in turn invariably lies above the Devonian. The complete thickness of the stratified rocks alone—or, in other words, their thickness exclusive of volcanic or igneous rocks—in Britain is given by Professor Ramsay as 72,584 feet, or, as Mr. Darwin has put it, "very nearly thirteen and three-quarters British miles. Some of the formations," continues Mr. Darwin, "which are represented in England by these beds, are thousands of feet in thickness on the continent. Moreover, between each successive formation we have, in the opinion of most geologists, blank periods of enormous length."

Now, it is these "blank periods" which certainly affect, in the plainest fashion, all questions concerning the operation of biological change in its relations to time past. It is necessary here to bear in mind a few elementary geological axioms, such as the fact that only those rocks (the *aqueous* or *stratified* rocks) which have been formed in water contain fossils; and that the igneous, or volcanic, rocks cannot be expected, from the mere fashion of their formation, to present any traces of past life. Thus it is clear the aqueous, or fossil-bearing rocks must have been formed either in the beds of oceans or in shallow water along coast lines, or in lakes, or at the mouths of rivers, the materials for these rocks being supplied by the wear and tear of previously existing formations. The nature of the included fossils is often the best guide to the exact site wherein the soft materials were deposited to form the strata of future epochs. Thus the presence of fossilised corals, star-fishes, and marine forms of fishes would indicate that the formations containing these fossils had been deposited in a sea-bed; just as the discovery of fresh-water shells and plants in another series of strata would show that these latter beds were of lake origin; or, as a mixture of fresh-water and marine forms would suggest that the strata had been deposited in brackish water.

The distinctness of any two or more series of strata is inferred by the geologist when he discovers differences in their included fossils, whilst he also possesses a criterion of their distinctness in their mineral characteristics. Now, each group of stratified rocks is more or less clearly characterised by possessing certain characteristic fossils, which in some cases may be absolutely confined and limited to the one group of formations, never passing into any other series; or may, on the other hand, extend from one group through another series, or even through several successive formations. But we are accustomed to note that certain fossils specially characterise each formation, and are characteristic of that formation, even when they may have been slightly developed prior to its period, or have passed beyond it into the next epoch. The comparative distinctness of the fossils in the several formations was formerly explained on the assumption, that at the close of each period the forms of life dwelling therein were extinguished and killed off by some sudden catastrophe. The life of the succeeding period was supposed to be produced by the special creation of new species; these in turn becoming extinct at the close of their particular epoch. Creation and extinction, on this theory, were thus alternating processes; the death of the one set of organisms heralded the production of the new and independent forms. Such a hypothesis, tenable enough, of course, on the theory of "special creation," is diametrically opposed to that of evolution. But the case for the latter hypothesis was soon proved to be overwhelmingly strong when the facts relating to fossils were more fully investigated. Thus, when it is clear that all the forms represented as fossils in one series of rocks are not, as a rule, completely absent from the succeeding epoch, but are often found represented in the next period, the case for the "special creation" of each new series of fossils becomes materially weakened. Furthermore, just as lines of genetic relationship connect existing animals and plants, so like relations may be traced between extinct and fossil forms. Hence the theory that the fossil animals and plants of each period must represent the more or less typical descendants of the life of the preceding epoch, at once rises into the domain of rational belief. If we can believe that each new period is thus peopled by the descendants of the preceding epoch, and by the actual survivals from that period, the case for evolution grows in strength; and this belief is exactly that which modern geological science esteems to have been the true cause of the succession of life through the changing æons of the past. "If the doctrine of evolution is sound," says Professor Huxley, "one of its immediate consequences clearly is, that the present distribution of life upon the globe is the product of two factors, the one being the distribution which obtained in the immediately preceding epoch, and the other the character and extent of the changes which have taken place in physical geography between the one epoch and the other; or, to put the matter in another way, the Fauna and Flora of any given area, in any given epoch, can consist only of such forms of life as are directly descended from those which constituted the Fauna and Flora of the same area in the immediately preceding epoch, unless the physical geography (under which I include climatal conditions) of the area has been so altered as to give rise to immigration of living forms from some other area."

The succession of life thus described offers convincing proofs of the correctness of the evolutionist's views, and these proofs will be presently considered. The nature and influence of the breaks or "blank periods" of Mr. Darwin, which exist between the series, remain, however, for primary notice. The geologist finds ample cause in his study of the rock-masses to assume that the periods of time which have elapsed between the end of one epoch and the beginning of the next, have been of immense duration. That these periods are further "blank," and unrepresented by any tangible details in the earth's history, is also plain. It is matter of geological detail, for example, to show how the phenomena known as "unconformability,"—wherein one rock system lies athwart another, so to speak—alone proves the immensity of the period of time which intervened between their formation. Prior to and during this interval, migration of the species to be represented as fossils in the epoch which had just closed, would unquestionably take place. We thus note how rocks formed in widely separated areas may contain like fossils, and also how the animals and plants of one period may have passed onwards to take part in the development of life in the next. Mr. Darwin's own words are highly succinct and convincing on the points just mooted. "I have given my reasons," says Mr. Darwin, "for believing that most of our great formations, rich in fossils, were deposited during periods of subsidence; and that blank intervals of vast duration, as far as fossils are concerned, occurred during the periods when the bed of the sea was either stationary or rising, and likewise when sediment was not thrown down quickly enough to imbed and preserve organic remains. During these long and blank intervals I suppose that the inhabitants of each region underwent a considerable amount of modification and extinction, and that there was much migration from other parts of the world. As we have reason to believe," continues Mr. Darwin, "that large areas are affected by the same movement, it is probable that strictly contemporaneous formations have often been accumulated over very wide spaces in the same quarter of the world; but we are very far from having any right to conclude that this has invariably been the case, and that large areas have invariably been affected by the same movements. When two formations have been deposited in two regions during nearly, but not exactly, the same period, we should find in both, from the causes explained in the forgegoing paragraphs, the same general succession in the forms of life; but the species would not exactly correspond; for there will have been a little more time in the one region than in the other for modification, extinction, and immigration." It thus seems clear, that on grounds connected with the lapse of past time in relation to life-development on our globe, and also for reasons connected with the "blank periods" between the formations comprising its crust, the evolutionist may be content to assume, firstly, that questions connected with the duration of time past need not cause him any perturbation. He may secondly argue, with reason, that even when the question of unrepresented periods is alone considered, the evidence at hand tends to prove how life's succession is in reality continuous beneath the breaks in time, and in the order of rock-formation; whilst he also notes how aptly the theory of descent harmonizes with the full consi eration of the facts revealed by a study of the earth's life-history in the past.

The question of the general succession of life on the earth's surface presents an important series of considerations to the evolutionist's view. In this latter study, it is interesting to note the theory of descent finds increased support. Admitting to the full the great breaks which exist in the continuity of the rock-formations comprising the crust of the globe—"blank periods" which in no way militate against the correctness of evolution—we still possess data of sufficient accuracy and extent to determine for us the general order in which life has been developed on the earth's surface. The further back we pass in the history of the rock-formations, the fewer are the resemblances we can detect to living animals and plants. Occasionally we meet with certain forms which seem to have persisted from the earliest times, and without material change, to the present day. Such are certain of those shellfish named *Brachiopods*, and also many of the *Foraminifera*. These have survived from a period so far back as the Silurian epoch; and appear before our eyes to-day as living forms, in essentially the same guise as their fossil representatives. Such examples of unaltering life have already been shown, in the chapter on "Degeneration," to be perfectly consistent with the doctrine of evolution. They represent species whose surroundings remain the same to-day as of yore, and whose tendencies to change are, therefore, practically non-existent. A glance at the table of rock-formations already given (page 368) will show that time past has been divided by the palæontologist into three great periods, in so far as the development of life is concerned. Thus the rocks from the Laurentian, or oldest of the fossil-bearing series to the Permian are collectively named "Palæozoic" (or "Ancient Life") formations. Those from the Trias to the Chalk form the "Mesozoic" (or "Middle Life") period; whilst the rocks from the Chalk to the soils of to-day collectively form the "Kainozoic" (or "Recent Life") period.

It is a matter of the most elementary study in geology to discover that the fossil animals and plants of the Palæozoic period are most unlike the existing life of the globe. The fossils of the Mesozoic rocks approach more nearly in character to the animals and plants around us, although also including many very divergent forms. In the Kainozoic rocks, on the other hand, we meet with a far larger proportion of fossils belonging to living or "recent" species. Broadly speaking, then, there has been a gradual development of life from forms unlike those around us to-day, towards the existing life of the globe. But geology goes much further in its interpretation of the past life of our globe. There has been represented, in addition, a distinct development of higher from lower life as the ages have progressed. There have been progression and advance, as well as mere succession towards the likeness of existing life. If we turn to the oldest rocks, we find the fossils to include only those of low or primitive animals and plants. It is only as we pass to the newer rocks that we find traces of higher life. If we select any class of animals or plants, we do not discover, as would be expected if the theory of "special creation" were true, that all ranks and stages in that class appear simultaneously in the fossil record. On the contrary, the lower forms invariably precede the higher. Fishes, as the lowest Vertebrates, thus precede other members of their type in time. The oldest fossil fishes occur in the Upper Silurian rocks; and it is not until we arrive at the newer Coal measures that we find the succeeding and higher class, that of the frogs or amphibians represented. In the deposits (Permian) above the Coal, the still higher reptiles first occur; birds make their first appearance in the Mesozoic rocks, and the oldest mammals or quadrupeds are also of Mesozoic age. What holds true of Vertebrate development, applies also to the appearance of life at large on the earth's surface. Where the fossil evidence that the lower members of a class appear before the higher seems doubtful, the discrepancy must be referred to that imperfection of the fossil record which constitutes an impassable barrier to our full and complete knowledge of the life of the past. But wherever sufficient materials are to be found, the great law of progression from lower to higher types of life is seen to be paramount as an expression of the manner in which the world has attained the fulness of its existing population. It need hardly be pointed out how powerfully the discovery of this progression in the past life of the globe supports the evolutionist's views. Instead of the sudden appearance of whole groups of high and unaltering organisms in the oldest formations, we are enabled to trace the gradual development of species. In the case of certain groups of animals, the evidence for the theory of development becomes singularly complete when we discover the exact course in which the evolution of new species by the modification of the old has taken place. Amongst the extinct trilobites and ammonites, for instance, the gradations between the various forms are often traceable with singular completeness; the gaps between the different species being frequently supplied in the most exact fashion.

A notable feature in the life of the past consists in the observation that many extinct animals present characters which clearly belong to the young or embryonic condition of their type, rather than to the full-grown state, or to that seen in their existing representatives. This fact constitutes in itself a singularly powerful argument in favour of the evolutionist's views. It shows that the progression of life in time past has been that which the development of animals to-day demonstrates. In other words, as the stages in development we see to-day repeat the ancestry of the developing animal, so these "embryonic" fossil forms represent the early and lower phases in the development of the species. The animal of to-day represents the cumulative advance of its race. It forms a striking confirmation of the evolution theory that we should discover in the *débris* of past epochs, and in the lower life of these epochs the actual evidences of such advance. The conception of the evolutionist that the development of life is represented by a huge tree with its innumerable diverging branches and twigs, is thus seen to fit the actual details of which his theory takes cognisance. The species of to-day represent the topmost or last developed leaves of the branches. Occasionally, we are able to trace the continuity of past and present along the branch and backwards to the stem. And even where this continuity is broken, it is interesting to note how the evidences of its former existence became clear, when, in the shape of the lower and earlier fossils, we behold the scars and lopped branches, showing the lines wherein the development of the past had progressed.

The imperfection of the geological record has already formed the subject of a previous discussion. We traced the absence of many of the connecting links between existing groups of animals to the non-preservation of the forms of the past, as well as to the wholesale destruction of fossil-histories which changes to the rock masses undoubtedly involved. Despite the effect of such sweeping physical revolutions, the evidence for the existence of these "links" between existent forms which evolution postulates, has been shown in not a few cases to be singularly complete. It is necessary, however, to refer more exactly in the present instance to the actual causes which have rendered the fossil record, at the best, of fragmentary nature. There are thus, firstly, certain groups of animals which, from the very nature of their habits, we could not expect to have been well represented by fossil species. Such forms as insects and birds, for example, could rarely be expected to become readily fossilised. Their habits lead them to exist in the majority of cases far from water; and the lightness of their bodies would largely preclude the probability of their frequent deposition amongst the *débris* of seas and lakes—such deposition being, of course, the natural prelude to their preservation as fossils. The comparative scarcity of bird and insect fossils fully attests the correctness of these deductions. What is true of these two groups holds equally good in the case of most land animals. By far the greater proportion of fossils consist of the remains of marine or aquatic forms, which naturally exist in the most favourable situation for becoming readily entombed in the soft deposits which form the rock-formations of the future. Another important consideration which has had a notable influence in demonstrating why we can never hope to construct a full and complete history of the past history of life-development, consists in the fact that only the hard parts of animals and plants are, as a rule, capable of being preserved. Bones, teeth, and scales, along with shells and corals, are the structures which most commonly constitute the "fossils" found in rock-formations. Although in a few instances the footprints of animals, the tracks of sea-worms, and even the impress of a jelly-fish have been discovered, the vast majority of fossils consist of the remains of those animals and plants which possessed hard parts and structures. If, therefore, we consider the enormous number of soft-bodied organisms which, in this way, can have left no trace whatever of their existence, one all-sufficient reason for the imperfection of the geological record is not difficult to find. Whilst this record is thus imperfect and at the best fragmentary, such evidence as we do possess regarding its nature will be found in no case to negative the conclusions to which evolution would guide us. The whole of the evidence which geology has to submit in reference to the life of the past, clearly points to the idea of progression and modification of living beings as the only hypothesis which can fully explain and connect the facts of cosmical history. He who runs may literally read with pleasure and profit the story of life which is written in the records of the rocks; and that story is one of evolution and modification. Of "special creation" the rocks tell no tale; and life at large has nothing whatever to say in support of a tradition which belongs to the pre-scientific era of human thought.

It may lastly be pointed out how closely and intimately the phases of geological history parallel those of biological growth. Time was, when every phase of geological action was regarded as the result of a sudden catastrophe. Sudden, physical revolution, was but the counterpart of that special and independent "creation" of living beings, in which the science of yesterday believed. To-day, with wider and truer conceptions of both physical and biological history, both theories have been consigned to oblivion. As the "uniformity" of geological action supersedes the catastrophes of the past, so the evolution of life replaces the idea of its sudden creation. In each case, the supernatural, unknowable action postulated by ancient belief, is replaced by an efficient cause, the nature and direction of which can be investigated by mankind. From a detached, abrupt, and disconnected theory of nature, we have advanced towards a harmonious explanation of this world's order, and towards a unity of cause, outside which, as the growth of science tends to show, no event of history, cosmical or human, can exist.

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